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SIMULATORS FOR MARINER TRAINING AND LICENSING

PHASE 3, TASK C: PERFORMANCE STANDARDS FOR MASTER LEVEL SIMULATOR TRAINING

MARCH 1982

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16. Abstracts
This phase of the USCG Training and Licensing project established a methodology for determining performance standards to be used in measuring simulator training effectiveness. The Computer Aided Operations Research Facility (CAORF) Shiphandling Simulator was utilized to measure the shiphandling performance of experts, i.e., pilots. Special scenarios were designed to cover a variety of training objectives relevant to shiphandling. These objectives included: approaching a harbor, responding to a rudder failure in confined waters, negotiating a 51° turn with passing ship effects, negotiating a 129° turn around a shoal with incoming traffic, and responding to a propulsion failure in the vicinity of a bridge and shoal. Fourteen pilots were run through these scenarios in order to assess the responses of shiphandling experts to the test situations. Fourteen chief mates, upgrading to the master level, were then run through the same scenarios. The chief mates were considered novice shiphandlers.

This report includes a detailed description of the test scenarios, performance measures, expert and novice data, and a method for deriving performance criteria to be used in assessing the effectiveness of simulator training.

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METRIC CONVERSION FACTORS

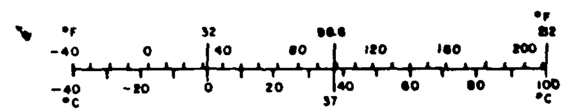
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

OBJECTIVE

This phase of the USCG Training and Licensing project established a method for determining performance standards to be used to assess the effectiveness of training shiphandling on a simulator. The Computer Aided Operations Research Facility (CAORF) located in Kings Point, New York was used in this research program.

METHOD OF APPROACH

Five scenarios were designed to measure five different aspects of shiphandling:

- Approaching a harbor
- Responding to a rudder failure in confined waters
- Negotiating a 51 turn with passing ship effects
- Negotiating a 129 turn around a shoal with oncoming traffic
- Responding to a propulsion failure in the vicinity of a *bridge and shoal*

It was reasoned that the level of performance which a trainee achieves in each of these test scenarios should improve after a simulator training program. However, it was **critical to demonstrate that these test scenarios were sensitive to various levels of performance**. To demonstrate this sensitivity the following research was conducted.

PROCEDURE

Fourteen active first class pilots with 80,000 DWT tanker experience considered expert shiphandlers by their peers, were asked to con an 80,000 DWT tanker through the five test scenarios.

Fourteen chief mates upgrading to master were then asked to perform the same tasks. These chief mates, while seasoned mariners, were minimally experienced in actual shiphandling. The two groups were then compared on their shiphandling performance through these five test scenarios.

PERFORMANCE MEASURES

The performance measures for each of the scenarios are listed below.

Scenario A. Shiphandling during Harbor Approach. Performance measures:

- Recognition that a buoy was off-station
- Mean deviation in feet off centerline
- Maximum deviation in feet off centerline
- Mean deviaton in feet off average trackline*
- *Maximum deviation in feet off average trackline*

Scenario 1, Shiphandling in response to a rudder failure in confined waters. Performance measures:

- Whether ownship collided with any of three anchored ships
- Whether ownship collided with the piers
- Closest point of approach (CPA) in feet to two of the anchored ships
- The amount of time in seconds it took to reduce ownship's speed to less than 2 knots
- The amount of time in seconds it took to reduce ownship's rate of turn to less than or equal to 0.1 degree per second.

*Average trackline refers to the trackline which best fits the route taken by the entire group of subjects.

Scenario 2, Negotiating a 51 turn with passing ship effects. Performance measures:

- Closest point of approach (CPA) in feet to an outbound containership
- Average swept path in feet
- Maximum swept path in feet
- Ratio of average swept path to channel width
- Ratio of maximum swept path to channel width
- Whether ownship grounded on the channel bottom

Scenario 3, Negotiating a 129 turn around a shoal with oncoming traffic. Performance measures:

- Average swept path in feet
- Maximum swept path in feet
- Ratio of average swept path to channel width
- Ratio of maximum swept path to channel width
- Whether ownship grounded on the channel bottom
- CPA in feet to a tug-tow

Scenario 4, Shiphandling in response to a propulsion failure in the vicinity of a bridge and shoal. Performance measures:

- Grounding on a shoal
- Collision with a railroad bridge

EVALUATION OF PERFORMANCE MEASURES

A 90% confidence interval about the pilots' average score was computed for each performance measure for each scenario. The lower limit of this confidence interval reflected the lowest value that the pilots' mean score could be, given a 90% level of confidence. Ths lower limit was then used as a cutoff score for adequate performance.

The data were then reanalyzed to determine the proportions of pilots (experts) and chief mates (novices) who scored better than this cutoff value. For the test scenarios to be deemed sensitive to various levels of shiphandling performance, the proportions of experts and novices who scored above the cutoff value would have to differ significantly. This was done using a χ^2 statistic. Results are summarized below.

RESULTS

Actual cutoff scores and the proportions of subjects who achieved these scores are reported in the appendix of this report. Below is a summary of those performance measures which adequately discriminated between pilots (experts in shiphandling) and chief mates upgrading to masters (novices in shiphandling).

Scenario A, Harbor Approach. Performance measures useful as training criteria:

- Recognition of buoy off station
- Mean deviation off centerline
- Maximum deviation off centerline
- Mean deviation off average trackline
- Maximum deviation of average trackline

Performance measures not useful as training criteria:

- None

Scenario 1, Rudder Failure. Performance measures useful as training criteria:

- Time to reduce speed (including collisions)

Performance measures not useful as training criteria:

- CPA to Ship 3 (including collisions)
- CPA to Ship 3 (excluding collisions)
- CPA to Ship 4
- Time to reduce speed (excluding collisions)
- Time to reduce rate of turn (excluding collisions)
- Collision with piers
- Collisions with either ship or pier

Scenario 2, 51° Turn. Performance measures useful as training criteria:

- None

Performance measures not useful as training criteria:

- CPA to outbound containership
- Maximum swept path
- Average swept path
- Maximum ratio swept path
- Average ratio swept path

Scenario 3, 129 Turn. Performance measures useful as training criteria:

- Maximum swept path
- Maximum ratio swept path

Performance measures not useful as training criteria:

- Maximum swept path
- Maximum ratio swept path

Performance measures not useful as training criteria:

- Average swept path
- Average ratio swept path

Scenario 4, Propulsion Failure. Performance measures useful as training criteria:

- Safe completion of transit

Performance measures not useful as training criteria:

- Groundings on shoal
- Collisions with bridge

SUMMARY

The phase 3 research was designed to establish performance standards for simulator training of chief mates upgrading to masters. Five different scenarios incorporating numerous training objectives were presented to pilots (expert shiphandlers) and chief mates (potential trainees) and their shiphandling abilities were measured. Four of the five scenarios yielded statistically valid performance standards. The methodology and results on the research are reported in detail in the text and appendices.

CHAPTER 1

INTRODUCTION

In response to the IMCO convention resolution on Standards of Training and Watchkeeping, all member maritime nations have agreed to establish a standard for graduates of maritime academies to have a minimum of one year of at-sea duty prior to licensing. Due to the cost associated with the maintenance and operation of vessels at sea, simulation has come to offer a viable and more cost-effective alternative to extending the current at-sea training periods. Furthermore, current U.S. legislation has called for the need to determine the effectiveness of simulation in meeting the requirements of the Port and Tanker Safety Act of 1978. In the interest of achieving these objectives, the multiphase Training and Licensing project has been jointly sponsored by the U.S. Coast Guard and the Maritime Administration, and is currently ongoing at CAORF. The goals of this project have been to develop criteria for accrediting simulator-based training programs in order to meet IMCO requirements, improve the safety of vessels operating in U.S. waters, and to protect the operator from suffering losses due to participation in ineffectual simulator-based training programs.

The development of these criteria can be approached in several fashions. One approach would impose standards on the design of the facility itself, as well as its training program and instructional personnel. A second approach would require graduates of the facility's training program to meet minimum performance criteria. A third approach utilizes a combination of both simulator design and performance standards.

Phases 1 and 2 of the Training and Licensing project focused on generating data to be used in the evaluation of simulator design characteristics. Phase 3 of the project focused on refining a method for establishing performance standards for those trained on shiphandling simulators.

This report addresses the criteria for simulator-based training systems at the master/chief mate level. It describes the methods used and results obtained in establishing performance standards for licensed individuals who have partaken in simulator-based shiphandling training programs.

CHAPTER 2

ESTABLISHMENT OF PERFORMANCE CRITERIA FOR SIMULATOR TRAINING

In investigating the use of performance testing as part of the mechanism for accrediting a master level simulator-based training program, it is apparent that such testing would ideally take place in the at-sea environment. However, staggering logistics plus a large element of risk made it desirable to employ a high fidelity simulator, such as CAORF, as a surrogate for the at-sea environment.

The rationale for using a high fidelity simulator in place of the at-sea environment is based on a "backward transfer of training" model. In this model, an operator who is proficient with respect to the desired specific functional objectives (SFOs) in the actual operational vehicle is transferred to the simulator, where he is required to perform tasks corresponding to the SFOs. If he can successfully perform such tasks with a high level of proficiency without practice on the simulator, then backwards transfer of training has been demonstrated. If trainees who have completed a simulator training program can then attain the proficiency levels on the simulator as established by the expert operators, they should exhibit a positive transfer of training when placed in the real world environment. It should be noted that this backward transfer of training model has been employed at COARF in the original CAORF validation (Hammell, 1977) and the evaluation of the Valdez Operational Exercises (Williams, 1978).

In designing the Phase 3 experiment, the first step was to select a standard of expertise in shiphandling which master level trainees could strive to attain. After considerable research and discussion, "minimally acceptable shiphandling" was designated as the proficiency with which pilots performed when removed from their areas of local knowledge. It was reasoned that a skilled pilot possesses two distinct sets of skills: one is his superior raw shiphandling ability, gained generally through frequent practice; and the second is his local knowledge, which to a great extent streamlines his shiphandling practices through foresight and past experience. Operating without local knowledge, pilot proficiency on a test scenario should then provide an indication of the performance of a "better-than-average" shiphandler, the level desired for master candidates.

To ensure that the scenario used in Phase 3 provided high levels of discrimination between entry level (chief mate-master) and expert (pilot) performance, exercises in shiphandling were administered to 28 subjects: 14 were chief mates upgrading to master, and 14 were pilots from around the country who were considered by their peers to be the best. The performance of both groups was then evaluated using the method described in Section 2.4.

A description of the performance test scenario along with associated results and conclusions from this experiment appear in the following sections.

2.1 THE PERFORMANCE TEST SCENARIO

The actual test scenario is comprised of five distinct legs, each designed to examine a particular aspect of shiphandling proficiency. The following paragraphs contain a brief description of the content and configuration of the various legs, as well as their objectives.

LEG A – Training Objective. Shiphandling in Harbor Approach – This segment was designed to replicate a typical "harbor approach" exercise. (See Figure 2-1.1.) Starting in open sea at a distance of approximately 8 miles from the pilot station, the subject was required to navigate and handle the vessel in a traffic separation lane which represented the approach to Port XYZ. This scenario was run for approximately 20 minutes and entailed the execution of the turn in the traffic lane, an endeavor which became complicated by the presence of traffic, navigational aids off station, etc. The subject had two excellent shore beacons for visual bearings, simulated radar, fathometer, and Loran C systems available for navigation. Also available was a new, simulated *Automation Direction Finder* display, providing digital readouts on two local radiobeacons. Necessary publications such as tide tables, weather reports, notices to mariners, etc. were also available for perusal. The scenario had been designed so that visual and radar scenes became intentionally misleading with an aid moved from its charted position. The adherence to the desired

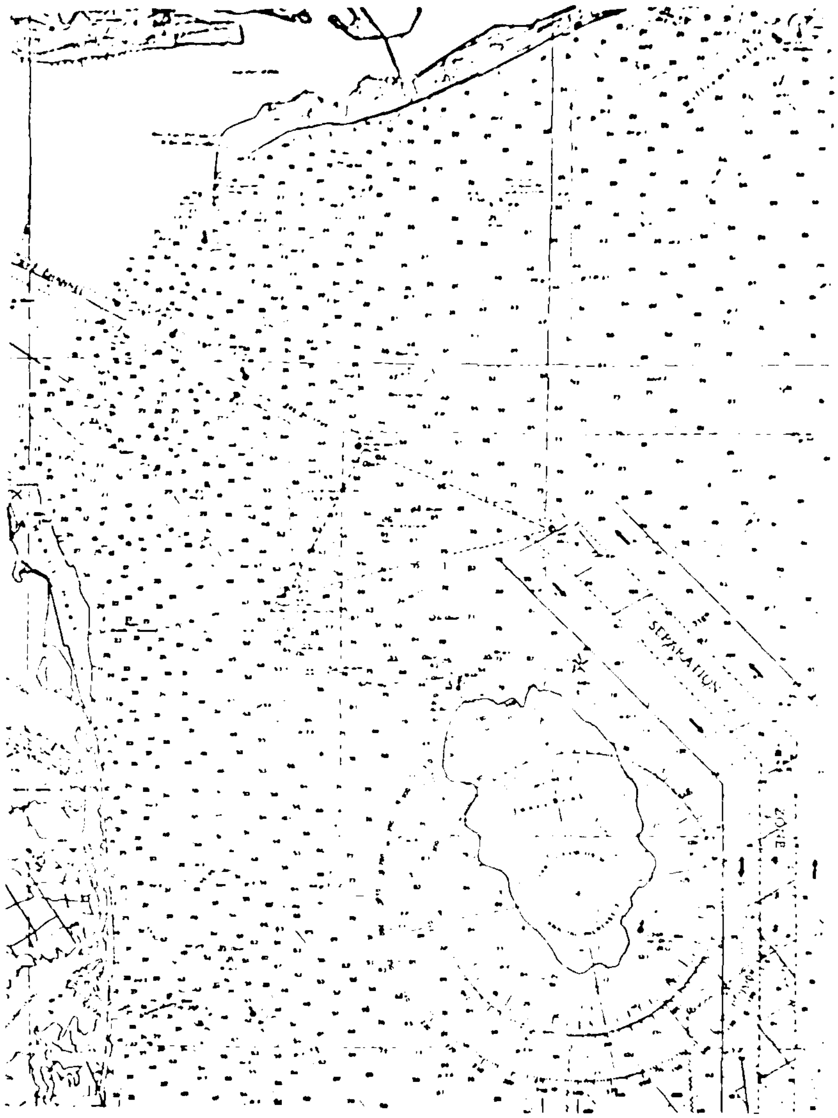

Figure 2-1.1. *Test Scenario Leg A*

track was only possible through the careful cross checking of navigational information from several of the inputs available.

LEG 1 – Training Objective: Shiphandling in Response to Rudder Failure in Confined Waters – Designed to examine the area of emergency shiphandling under rudder failure conditions, this leg commenced in upper Wyassup Bay, approximately 1 mile south southeast of the "KV" buoy at the Gibson's Channel entrance, and ran for approximately 15 minutes. (See Figure 2-1.2.) At this point, a vessel speed of 8 knots was most normal and the ship had not yet picked up any escort tugs. Confined conditions were created in this seemingly open water area by placing a line of these anchored ships along the easternmost boundary at Kingston anchorage. Approximately 60 seconds into the

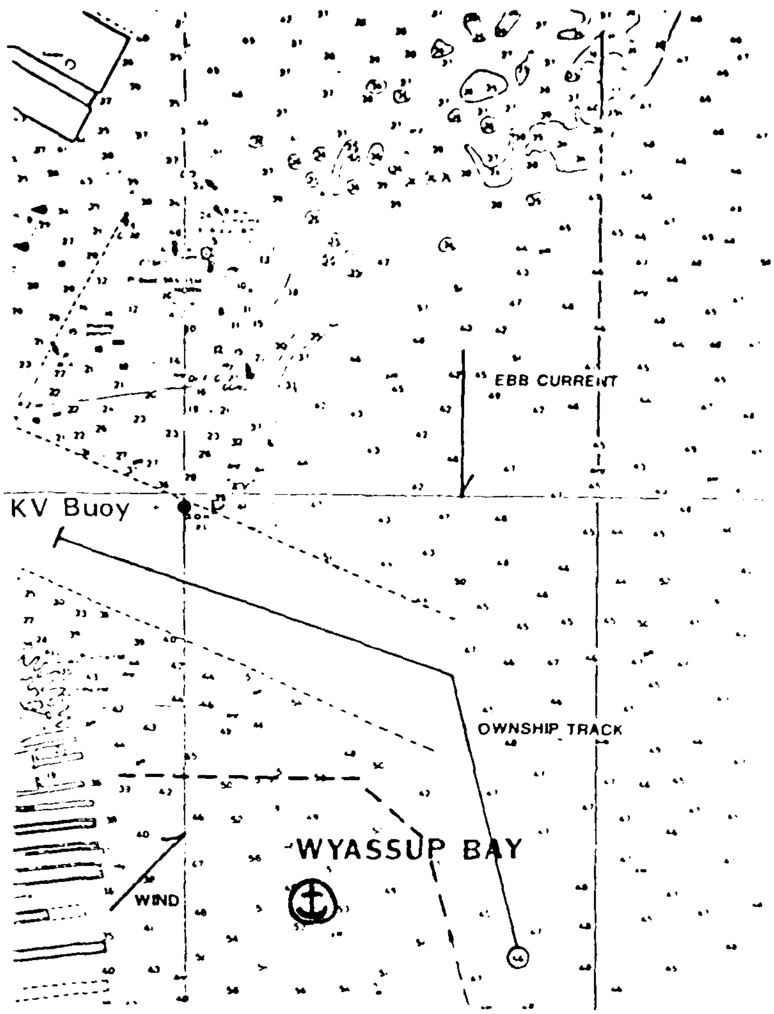

Figure 2-1.2. Leg 1

run, the subject was presented with a rudder failure, jammed at 15 degrees left, in the presence of wind and current. Any request by the subject for use of anchors was countered by a phone call from the bow stating that the windlass brake bands had jammed (anchors were therefore unusuable). One of the two hypothetical escort tugs responded to any distress call made, but did not arrive before the run terminated. The tugs were shown visually as approaching slowly from a good distance ahead. The subject did not receive rudder control back, forcing him to use thruster and engine power to maintain a safe aspect.

LEG 2 — Training Objective: Navigating a 51 Degree Turn with Passing Ship Effects — This segment examined the area of integrated shiphandling, that is, shiphandling in the presence of physical forces such as wind and current, as well as other vessels in similar environment. (See Figure 2-1.3.) Subjects began at 6 knots, misaligned on the Ferry Point Range. Achievement of proper alignment and negotiation of the 51 degree bend was rendered somewhat more difficult by the presence of an outbound containership, which met ownship near the apex of the channel bend.

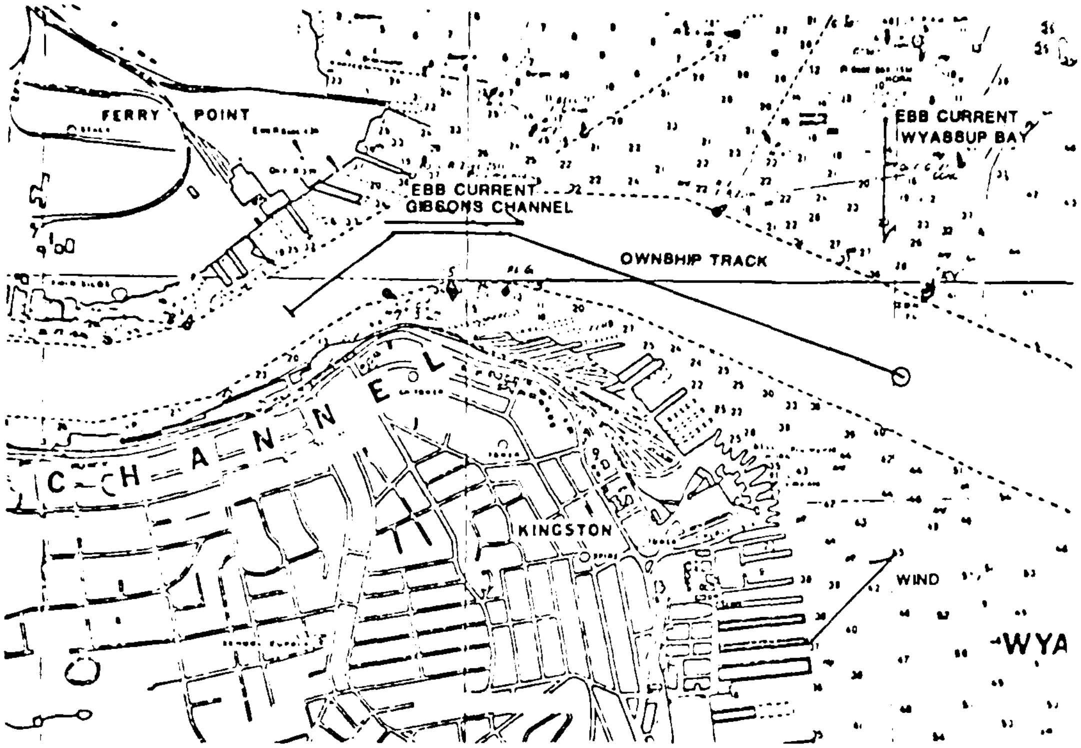

Figure 2-1.3. Leg 2

LEG 3 – Training Objective: Negotiating a 129 Degree Turn Around Shoal with Oncoming Traffic – This leg took its predecessor one step further in that the bend to be negotiated was now a 129 degree blind turn. (See Figure 2-1.4.) Initial speed was again 6 knots, and wind, current, and traffic were present to make more difficult the execution of the turn.

LEG 4 – Training Objective: Shiphandling in Response to Propulsion Failure in Vicinity of Bridge and Shoal – This segment examined emergency shiphandling as a result of propulsion plant failure. It took place in that area of Shellfish Bay which lies above the terminus of Leg 3, and involves a drawbridge transit in the presence of a power failure. (See Figure 2-1.5.) With an initial speed of 6 knots, the scene began approximately 0.3 nautical miles below the bridge with escort tugs on either bow announcing that their lines were in and that they were proceeding ahead through the draw. When the vessel was 0.1 nautical miles from the drawspan, RPM went to zero and the chief engineer called to announce that the plant had failed. A natural gas pipeline in the area precluded any use of an anchor, so the subject had to use the rudder and the bow thruster judiciously in order to negotiate the bridge passage. Throttle power did not return, and the scene ended upon contact with, or safe passage through, the bridge. It should be noted that although the bridge transit was difficult without propulsion machinery, it was an entirely plausible concept, as well as a totally attainable goal.

2.2 SUBJECTS

Masters

The masters who participated in the experiment were selected to represent a cross-section of those entry level shiphandlers who would benefit most from this type of simulator-based training. The basic qualifications of these subjects were:

1. To hold a current master's certificate but have no previous experience as master.

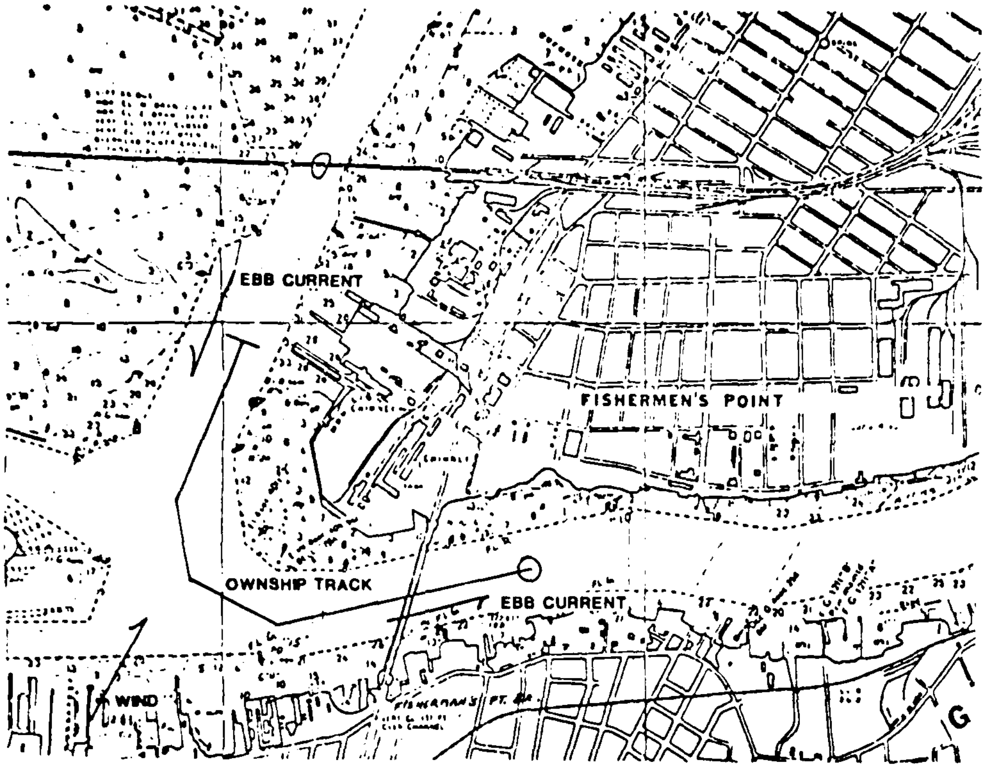

Figure 2-1.4. Leg 3

2. To have experience aboard tankers in the 80,000 DWT range.

To obtain a representative sample, a broad range of shipping companies were contacted and asked to supply a list of people who fit the experimental requirements and who would be available for the experiment (Maritime Overseas, Chevron, Aroo, Exxon, Gulf, Keystone, Zapata, Trinidad, Ogden Marine). From this list of names, individuals were randomly selected and contacted until the full complement of 14 subjects was reached.

Before the experiment began, biographical data were collected to determine the background and actual experience of the men used in the sample. It was found that of the 14 subjects, six had sailed as chief mate aboard 80,000 DWT tankers. Two of these individuals acted as mooring masters aboard their vessels, but had no experience with shiphandling in channels. The remaining eight subjects had chief mate experience on board tankers in the 60,000 to 70,000 DWT range.

The masters ranged in age from 31 to 57 years old with an average age of 40 years old. The group had an average of 15 years of experienced as licensed deck officers with a range of eight to thirty years.

Pilots

The qualifications for the expert shiphandler category required that the men chosen:

1. Be active first class pilots with 80,000 DWT tanker experience.

2. Be members of recognized pilot associations.

3. Be selected and judged by peers to be expert.

4. Have no pilotage or experience in New York Harbor.

Pilot associations in Boston, Delaware, Houston, and San Francisco were contacted and asked to provide individuals

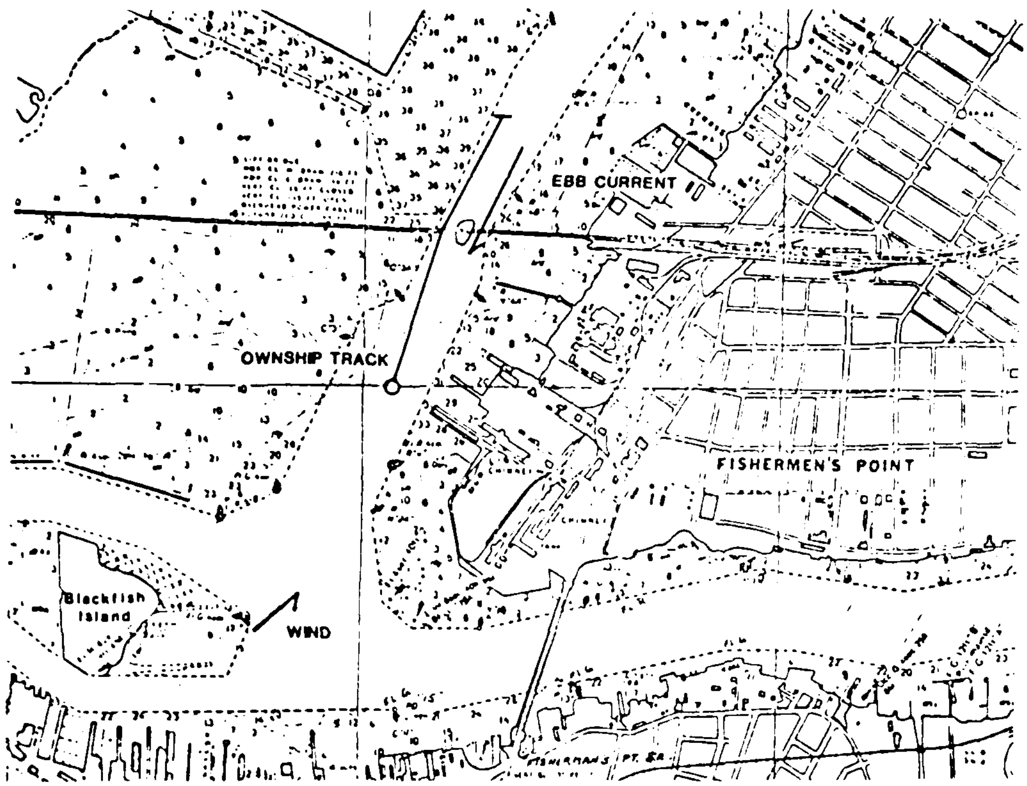

Figure 2-1.5. Leg 4

who were judged to represent the expert shiphandlers in these associations. In this sample, there were four Boston pilots, five Delaware River pilots, four Houston ship channel pilots, and one San Francisco Bay pilot. The men ranged in age from 29 to 63 years old with a mean age of 42 years old. Within the group there was an average of 18 years of shiphandling experience and a range from 11 to 35 years of shiphandling experience.

2.3 PERFORMANCE MEASURES

Measures of performance were selected either because of their direct relevance to training objectives (e.g., Did the subject notice that one of the buoys in Leg A was off station?) or because logical inferences about shiphandling and controllability could be drawn from these measures (e.g., How closely did the subject keep on track?). The dependent measures used in this study were also selected for their sensitivity to manipulation of independent variables.

The performance measures used for each training objective are described below.

Leg A — Training Objective: Shiphandling in Harbor Approach

Recognition of Buoy Off-Station

It was hypothesized that pilots would attend to this information more than masters. Given that a subject noticed the buoy off station, he could have maneuvered to the left of the buoy in order to stay on track. Such a maneuver to port would have minimized off track deviation. However, in light of the fact that a traffic ship was approaching ownship at about the time of maneuver, the subject may have noticed the buoy off station but maneuvered to the right anyway so as not to confuse the traffic ship. Thus, the critical measure was whether the subject noticed that the buoy was off station. Maneuvering either to the left or the right of the buoy was not necessarily a measure of good performance, since both maneuvers could be considered prudent.

Mean Deviation in Feet Off Centerline

This measure was computed by summing the absolute values of deviations off centerline and dividing by the number of deviations.

Maximum Deviation in Feet Off Centerline

This was the absolute value of the maximum deviation off centerline.

Mean Deviation in Feet Off Average Trackline

The average trackline for each group of subjects was computed and mean deviation from this trackline was derived using the technique employed for centerline.

Maximum Deviation in Feet Off Average Trackline

This measure was the absolute value of the subject's maximum deviation off his group's average trackline.

CPA to the traffic vessel was not considered a performance measure because the scenario's objective was not one of collision avoidance. The traffic ship in Leg A was placed there to add realism to the scenario and to affect the subject's maneuver with respect to the buoy off its station.

Leg 1 – Training Objective: Shiphandling in Response to Rudder Failure in Confined Waters

Collision with Anchored Ships

In this leg a rudder failure occurred when ownship was passing by three anchored ships. A direct measure of shiphandling skill in this situation was whether or not ownship collided with the anchored ships.

CPA in Feet to Anchored Ships 3 and 4

Ship 3, the northernmost anchored ship, was the ship most susceptible to collision as a result of the rudder failure. If the subject did not accelerate sufficiently to pass Ship 3, a collision occurred. Ship 4, the middle anchored ship, was most vulnerable to collision as a result of the subject's failure to reduce the turn rate of ownship. The closest point of approach of ownship to either of these vessels was measured and reported in feet.

Whenever the CPA to Ship 3 or 4 was zero (indicating a collision), the CPA data were reported both including and excluding collisions.

Time (in Seconds) to Reduce Speed Over Ground to Less Than 2 Knots

In response to the rudder failure in Leg 1, the subject had to reduce the speed of ownship in order to avoid collision with either the anchored ships or piers. The time it took each subject after the rudder failure to reduce his speed over ground to greater than 2 knots was calculated in seconds. These data were reported for those subjects who had collisions as well as those subjects who had not. In the event that ownship never reached a speed greater than 2 knots, the minimum speed was used.

Time (in Seconds) to Reduce the Rate of Turn to Less Than or Equal to 0.1 Degree Per Second

In response to the rudder failure, each subject had to use his shiphandling ability to reduce ownship's rate of turn (ROT). The time it took each subject after the rudder failure to reduce the ROT to less than or equal to 0.1 degree second was calculated in seconds. Where 0.1 degree second was not attained, the minimum ROT was used. These data were also reported for those subjects who had collisions as well as those who had not.

Collision with Piers

This performance measure indicated whether ownship collided with the piers after successfully negotiating the turn around the anchored ships resulting from rudder failures.

Leg 2 – Training Objective: Negotiating a 51 Degree Turn with Passing Ship Effect

CPA (in Feet) to Ship 3, Outbound Containership

Ship 3 was an outbound containership which ownship had to avoid. The CPA was reported in feet.

Average Swept Path (in Feet)

The average value of ownship's swept path measured in feet throughout Leg 2 was computed.

The maximum value of swept path reached in Leg 2 by each subject was also determined. This measure is more sensitive than average swept path since large values are not "washed out" by smaller values, as in the case of average swept path.

Average Ratio Swept Path

The average swept path in feet was divided by the channel width to create a measure which indicates the percentage of channel width taken up by ownship.

Maximum Ratio Swept Path

This measure was similar to that described above; however, the maximum swept path was used in the numerator rather than the average.

Grounding

The distance between the keel of ownship and the channel bottom was monitored throughout this leg. Whenever this distance reached zero, a grounding was considered to have occurred. The scenario, however, continued until a collision occurred or until normal termination.

Leg 3 – Training Objective: Negotiating a 129 Degree Turn Around Shoal with Oncoming Traffic

Average Swept Path (in Feet)

This was computed in a manner similar to Leg 2.

Maximum Swept Path (in Feet)

This was computed in a manner similar to Leg 2.

Average Ratio Swept Path

This was computed in a manner similar to Leg 2.

Maximum Ratio Swept Path

This was computed in a manner similar to Leg 2.

Grounding

These measures were computed in a manner similar to Leg 2.

CPA (in Feet) to Ship 8, Tug-Tow

Ship 8 was a tug-tow approaching ownship in Leg 3. Where CPA was equal to zero, a collision occurred. CPA to Ship 8 was reported for those subjects who had collisions and those who had not.

Leg 4 – Training Objective: Shiphandling in Response to Propulsion Failure in Vicinity of Bridge and Shoal

Grounding on Shoal

These data were reported for those subjects who grounded out and those who did not. It is a dichotomous variable.

Collision with Railroad Bridge

This is a dichotomous variable; either a subject hit the bridge or he did not.

Safe Completion of Transit

A subject was considered to have safely completed the transit if he did not ground out or collide with the bridge.

2.4 APPROACH TO EVALUATION OF PERFORMANCE MEASURES

A measure which can be used as a valid test of shiphandling ability must first and foremost be sensitive to degrees of proficiency in shiphandling. In order to demonstrate the sensitivity of a performance measure, one must show either that experts differ from novices with respect to that measure, or that the score achieved by a novice on that measure will change in a favorable direction as a result of training.

The performance measures utilized in Phase 3 were selected because previous CAORF research indicated their sensitivity to training or because they appeared to be directly related to the training objectives. However, in order for a measure to be used as a standard for evaluating shiphandling proficiency, it must be sensitive to degrees of proficiency. Thus, expert shiphandlers should perform differently than novices on any measure used to evaluate shiphandling.

With this in mind, a strategy for evaluating each performance measure was adopted. A flow chart of this strategy appears in Figure 2-4.1.

The first issue in evaluating each performance measure dealt with whether or not most experts (pilots) performed better than most novices (masters) with respect to that measure. It was difficult to answer this question when only 14 of each group were used as representatives. Any statistical test used to evaluate differences between these groups

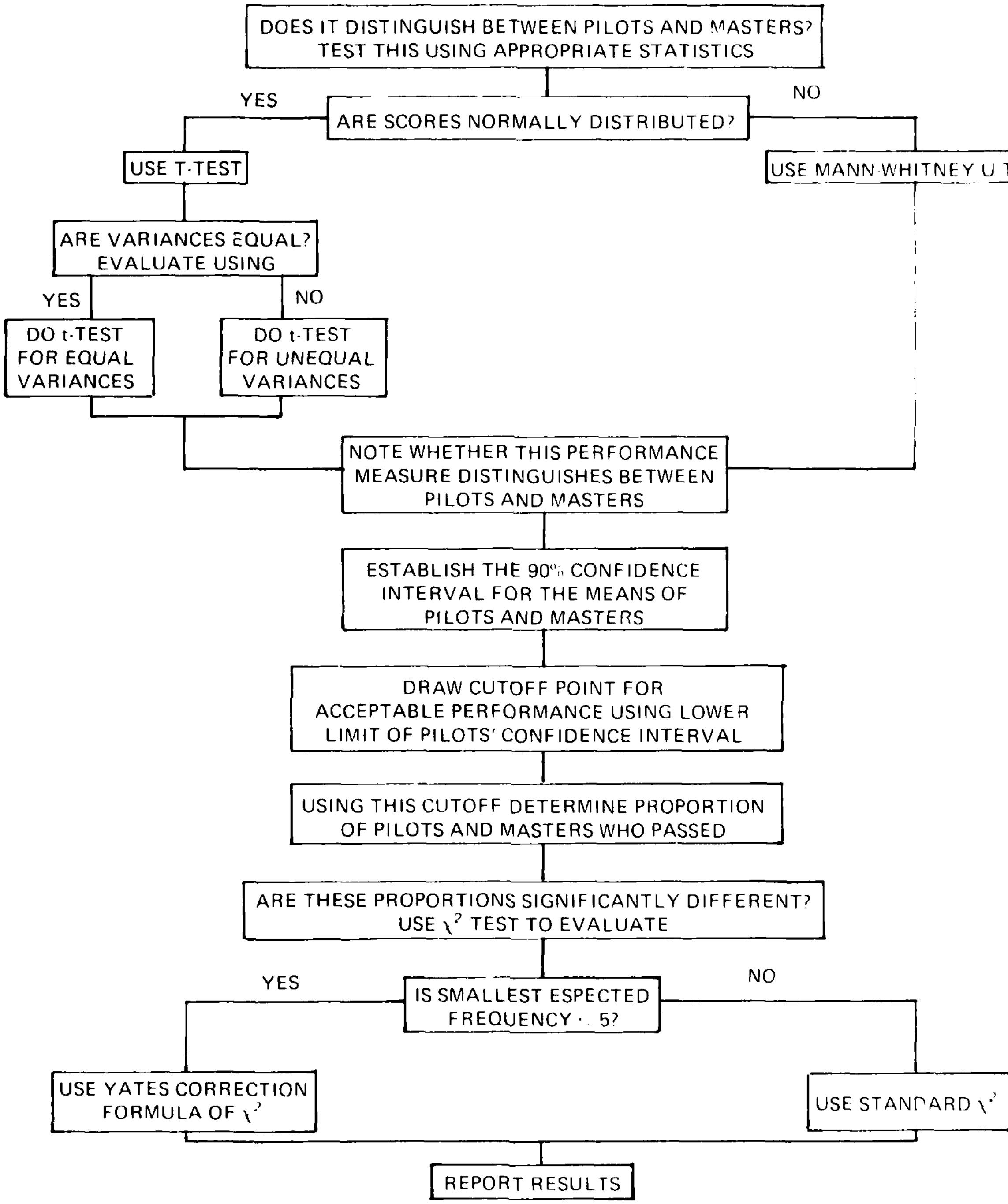

Figure 2-4.1. Strategy for Evaluating Each Performance Measure

must deal with a skewed distribution of scores and the loss of statistical power associated with small sample size (Cohen, 1969).

If the scores were normally distributed, then the t-test for independent samples would be the appropriate test of group differences. If the population variances were unequal, the formula for computing it should be modified according to the method described by Cochran and Cox (1954). If the scores were not normally distributed, then the Mann-Whitney U test is most appropriate (Siegel, 1956). These two statistical techniques should yield quite similar p values (probability of occurrence by choice) when the distributions of scores are approximately normal.

The next major issue in evaluating the performance measures was to establish a cutoff score for each measure. This cutoff score should reflect the difference between the performance of experts (pilots) and novices (masters). To accomplish this, a 90 percent confidence interval was drawn around the mean of the pilots. The lower limit of this confidence interval reflected the lowest value that the pilots' mean could be, given a 90 percent level of confidence. Using this value as a cutoff score, the data were reanalyzed to determine the proportions of pilots and masters who scored better than this value.

For a performance measure to be valid, a larger proportion of experts should "achieve" the cutoff score compared to novices. Therefore, a 2 x 2 contingency table was created for each measure. This table reflected the number of pilots who scored better than the cutoff scores (achieved criterion) or worse than the cutoff score (did not achieve criterion) and the number of masters who did likewise. In order to determine whether the proportion of pilots who achieved criterion was significantly greater than the proportion of masters who achieved criterion, a χ^2 statistic was computed. Where the smallest expected frequency in the 2 x 2 table was less than five, the Yates correction formula for χ^2 was applied (Ferguson, 1976).*

All p levels reported in this paper are for one-tailed tests, since this research was only interested in establishing performance criteria above the mean of the masters. Thus, only one direction was of interest.

2.5 RESULTS

Leg A – Harbor Approach – Training Objective: Shiphandling in Harbor Approach

Five performance measures were evaluated in order to determine a subject's ability to handle ownship in a harbor approach situation where an important turn buoy was off station. Each subject's actual track plot is shown in Figures A-1 through A-14 for masters and Figures A-15 through A-28 for pilots.

a. Harbor Approach – Recognition of Buoy Off Station – The off-station buoy was particularly important since it marked the turn in the middle of a separation zone. It is indicated in each plot by a black dot in the vicinity where each ship altered course. Some subjects who noticed that the buoy was off-station passed on the left side of the buoy in order to stay in the lane. Other subjects who recognized that the buoy was off-station passed on the right side of the buoy. This occurred even though the subject noticed the placement error so as not to confuse an oncoming vessel. This procedure is not incorrect since ownship is in open waters and there is no other immediate danger. A determination was made as to which subjects noticed that the buoy was off station and a summary of these data appears in Table 2-5.1.

TABLE 2-5.1. NUMBER OF SUBJECTS WHO NOTICED BUOY OFF STATION AND POSITION OF BUOY DURING TRANSIT LEG A, HARBOR APPROACH

	Noticed Buoy	Passed With Buoy On		Did Not Notice Buoy
		Right	Left	
Masters	6	3	3	8
Pilots	13	11	2	1

*The authors of this report are quite aware of the arguments regarding the appropriateness of χ^2 when small frequencies occur. Results are given with and without Yates correction when the smallest expected frequency is less than five. The interested reader should consult Bradley et al., 1979, for a succinct treatment of this topic. Ferguson (1976, p. 201), Siegel (1956, p. 78), and Hayes (1973, p. 725) also provide discussions of this matter.

With the exception of one subject, all pilots noticed the buoy discrepancy. In contrast, more than half of the masters did not notice that the buoy was incorrectly located. A chi square analysis proved these differences to be significant ($\chi^2(1) = 8.02$, $p < 0.01$). Thus, this measure appears particularly valuable in distinguishing master and pilot behavior in approaching a new harbor.

b. Harbor Approach – Mean Deviation Off Centerline – This measure yielded significant differences between the performance of masters ($x = 1028.6$ and pilots ($x = 757.4$). A Mann-Whitney analysis yielded a $U(14, 14) = 65$, $p < 0.001$. The adoption of the lower end of the 90 percenter confidence interval about the mean for pilots (906.3 feet) as an achievement criterion shows a significant number of pilots having achieved this criterion (11 of 14). The proportion of masters and pilots who achieved this score is significantly different ($\chi^2(1) = 5.25$, $p < 0.025$) and suggests that mean deviation off centerline should be considered as a criterion for simulator training with respect to the characteristics defining this leg. Statistical details and graphic representation of the data are given in Figures A-29 through A-31.

c. Harbor Approach – Maximum Deviation (in feet) Off Centerline – The masters' and pilots' scores on this measure were not significantly different ($x = 2324$ and $x = 1915$, respectively). The lack of significance is most likely due to the wide variation of scores within each group. However, when the 90 percent confidence limit is calculated and a criterion score derived (2289 feet), 11 pilots achieve this score compared to five masters. These proportions are significantly different ($\chi^2(1) = 5.25$, $p < 0.025$). These data are summarized in Figure A-31 and shown graphically in Figure A-32.

d. Harbor Approach – Mean Deviation (in feet) Off Average Trackline – An average trackline for this leg was computed for masters and pilots. Due to mechanical recording failures, the data from two subjects could not be included in the average track for pilots. Therefore, all data and analyses concerning pilot performance is based on an $N = 12$ rather than 14.

The composite tracklines for masters and pilots are shown in Figures 2-5.1 and 2-5.2 and appear almost identical indicating that, on the average, both masters and pilots approached the harbor entrance in the same manner. The coordinates of the composite trackline for each group served as the basis for the calculation of mean deviation (in feet) and maximum deviation (in feet). The mean deviation off average trackline is reported below.

An analysis of the data shows (Figure A-33) that the mean deviation for masters referenced from their own trackline was 520 feet while pilots only deviated on the average of 300 feet. The difference between these scores is significant ($t(24) = 2.82$, $p < 0.01$) and indicates that pilots tend to vary their approach to the harbor less than masters. The 90 percent cutoff score, 384 feet, resulted in ten of the twelve pilots achieving criterion while only five of fourteen masters reached this level. These proportions differ significantly ($\chi^2 = 6.00$, $p < 0.01$) and indicate that this measure should be considered in defining adequate performance. These results are shown graphically in Figure A-34.

e. Harbor Approach – Maximum Deviation (in feet) Off Average Trackline – Since mean deviation (see above) and maximum deviation scores are related, it is not surprising to also find significant differences in maximum deviation off average trackline between masters and pilots. The mean maximum deviation for masters was 1920 feet and for pilots was 1079 feet. The resulting t-test yielded significance at $p < 0.01$ ($t(24) = 2.99$). Details of the data are shown in Figure A-35.

Using a 90 percent cutoff score of 1455 feet, 8 of 12 pilots achieved criterion and only 3 of 14 masters achieved criterion. These proportions are sufficiently different ($\chi^2 = 5.42$, $p < 0.05$) to warrant consideration of this measure as a discriminator of performance between masters and pilots. Graphic representation of the data is given in Figure A-36.

Summary of Leg A Harbor Approach

Performance measures useful as training criteria:

- Recognition of buoy off station
- Mean deviation off centerline
- Maximum deviation off centerline
- Mean deviation off average trackline
- Maximum deviation off average trackline

Performance measures not useful as training criteria:

- None

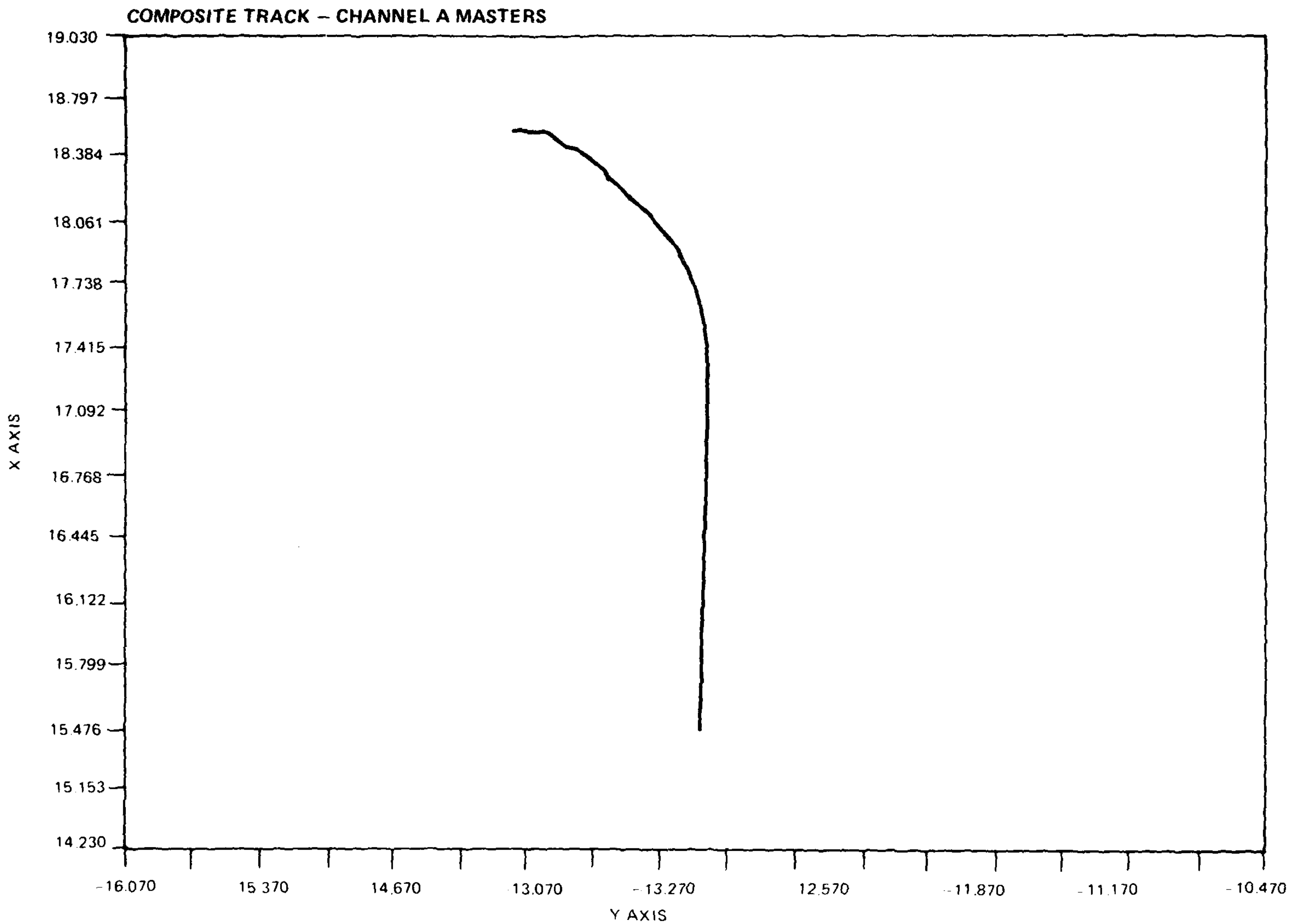

Figure 2-5.1. Composite Trackline, Masters, Leg A

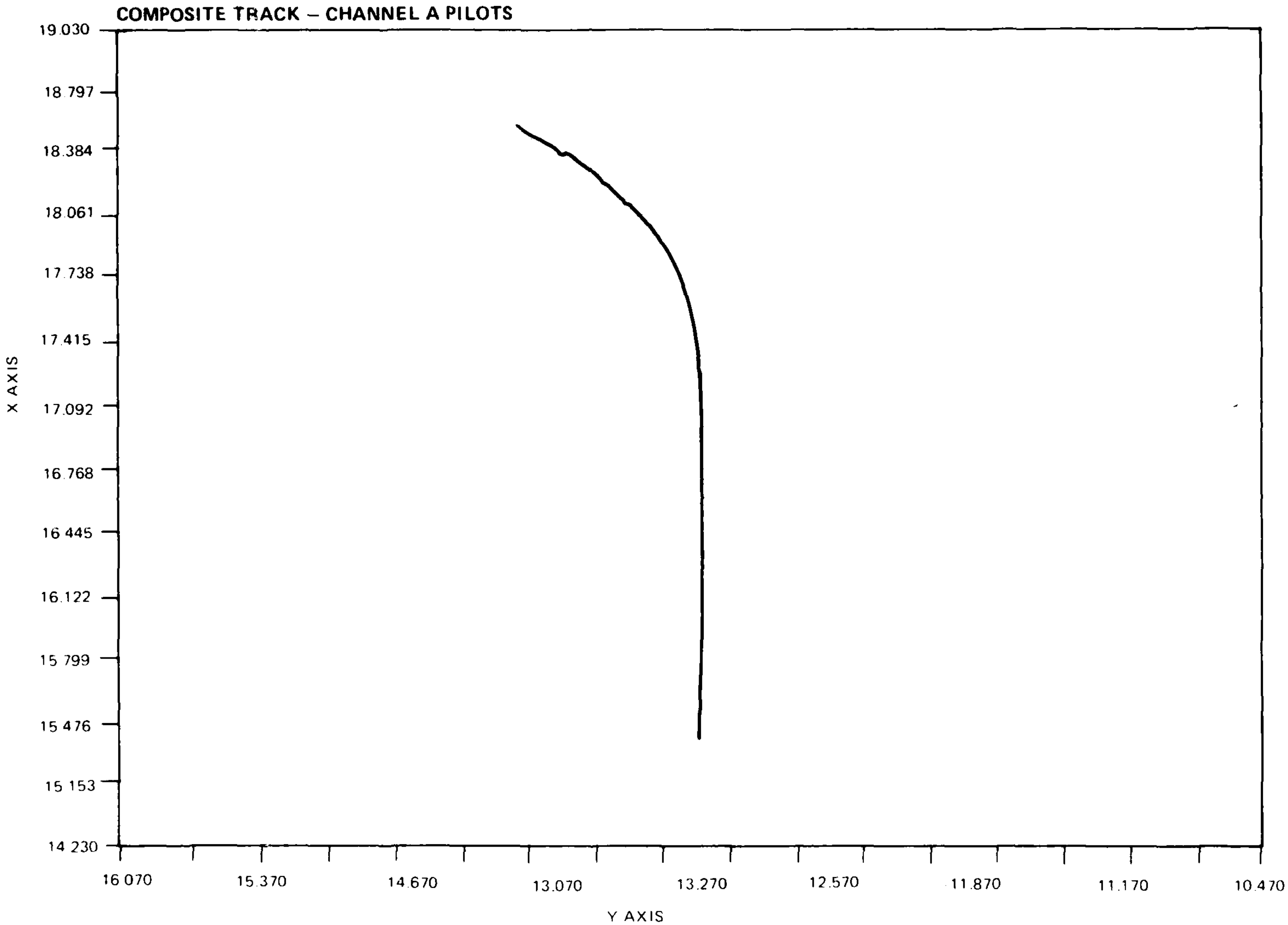

Figure 2-5.2. Composite Trackline, Pilots, Leg A

Leg 1 – Rudder Failure – Objective: Shiphandling in Response to Rudder Failure in Confined Waters

Track plots are shown in Figures B-1 through B-14 for all masters and in Figures B-15 through B-28 for all pilots. The plots show course of ownship with respect to the three stationary ships and the closest land mass. The northern-most anchored ship was designated Ship 3, and the vessel anchored somewhat below was designated Ship 4. CPA data excluding and including collisions was calculated for both these ships. The track plots show the obvious problems with which subjects were faced after the rudder failure. Subjects were primarily concerned with gaining sufficient control of ownship to avoid hitting Ships 3 or 4 and, after clearing them, to avoid colliding with the piers. In all, six performance measures were analyzed in evaluating his objective.

a. Rudder Failure – CPA to Ship 3 – The data for this measure were calculated in two ways. The first included those subjects who collided with anchored Ship 3, and the second analysis excluded these individuals. A summary of these data is presented in Figures B-29 and B-31 (those who collided with Ship 3) and Figures B-30 and B-32, respectively (those who did not collide with Ship 3). This information is detailed in Table 2-5.2.

Table 2-5.2 shows that in general pilots experienced more collisons than masters. Excluding these four pilots and one master, the resulting average CPA of the remaining subjects showed no significant differences. However, when all subjects are considered, regardless of whether they collided or not, the difference between the group means ($\bar{x}$ of masters = 326 feet and $\bar{x}$ of pilots = 188 feet) was significant, $t(26) = 1.825$, $p < 0.05$ show pilot and master mean CPAs. The 90 percent confidence limits were calculated for both cases (including and excluding collisions) and cutoff scores calculated. The number of pilots and masters achieving this criterion score was then counted. In both cases, the proportion of masters achieving criterion was not significantly different from that of pilots.

TABLE 2-5.2. MEAN CPA (IN FEET) TO SHIP 3, LEG 1, RUDDER FAILURE

Including Collisions*		Excluding Collisions	
Masters (N = 14)	**Pilots (N = 14)**	**Masters (N = 12)**	**Pilots (N = 10)**
326.3	188.2	351.4	263.7

*$p < 0.05$.

b. Rudder Failure – CPA to Anchored Ship 4 These data, detailed in Figures B-33 and B-34, show masters ($\bar{x}$ = 1075.9 feet) achieving a larger CPA than pilots ($\bar{x}$ = 922.8 feet) with a significant difference between these two means ($t(26) = 1.926$, $p < 0.05$). Using a cutoff score of 826.9 feet, masters and pilots did not differ in the proportions who scored above and below this cutoff. (See Figure B-32.)

c. Rudder Failure – Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots These data were also calculated including collisions (Figure B-35) and excluding collisions (Figures B-37 and B-38).

The difference between the means of each group excluding those subjects who collided proved non-significant. However, when all subjects are taken into account, the difference between these means was significant ($t(26) = 1.88$, $p < 0.05$. The use of the lower end of the pilot 90 percent confidence interval as a cutoff resulted in 11 of 14 pilots and 6 of 14 masters equalling or surpassing this score. The difference between these proportions is significant ($\chi^2(1) = 3.74$, $p < 0.10$).

It should be noted that pilots experienced more collisions than masters and the scores of the pilots who collided tended to be in the lower range of the group; thus, they contributed toward making the pilots' performance appear better than the masters'. Since whether a subject has a collision or not is the ultimate measure of good shiphandling, it appears valid to compute the scores excluding collisions in this instance. When this is done, no significant difference appears in any of the calculated statistics and it becomes doubtful whether or not this measure is of much use in setting standards for training.

d. Rudder Failure – Time (in seconds) to Reduce Rate of Turn to Less Than or Equal to 0.1 /Sec. The utility of this performance measure appears questionable. Scores of masters and pilots were fairly evenly interspersed throughout the range and none of the statistical tests showed any signficnce. This was true whether the scores included or excluded those subjects who had a collision. A summary of these data appears in Figures B-39 through B-42.

e. Rudder Failure – Collision with Piers – Only two masters (no pilots) collided with the land and/or piers following a successful clearing of Ship 3. This points to a possible superiority in pilots, but it is difficult to make any inference with such a small sample size.

f. Rudder Failure – Collision with Either Ships or Piers – The number of pilots and masters who collided with either anchored Ship 3, anchored Ship 4, or the piers was calculated. In total, four pilots and three masters collided with one of the three structures referenced above. This difference is not statistically significant and, therefore, this measure does not appear to be useful as a training criterion.

Summary of Leg 1 – Rudder Failure

Performance measures useful as training criteria:

- Time to reduce speed (including collisions)

Performance measures not useful as training criteria:

- CPA to Ship 3 (including collisions)
- CPA to Ship 3 (excluding collisions)
- CPA to Ship 4
- Time to reduce speed (excluding collisions)
- Time to reduce rate of turn (excluding collisions)
- Collision with piers
- Collisions with either ship or pier

Bridge Behavioral Data for Leg 1, Rudder Failure – In general, masters tended to exhibit slightly more thruster activity than pilots (30 thruster orders for masters versus 22 for pilots). As expected, the majority of thruster activity for both groups occurred immediately following the rudder failure. Masters and pilots appeared to differ in the manner in which each group responded to the rudder emergency. Pilots used a higher percentage of orders calling for "full" thrusters (72 percent) than masters, where only 60 percent of thruster orders given were for "full." The use of "full" thrusters by pilots extended throughout the run. All pilot orders (with the exception of one) were for "full" or "zero" thrusters. In contrast, masters occasionally used 3/4 or 1/2 thruster during this leg. In fact, during the first third of the run, and immediately following the rudder failure, not one pilot used the thrusters in any other mode except "full." It is not until four or more minutes after the failure that pilots reduce thruster activity. In summary, both groups responded to the rudder failure with thruster activity, but pilots tended to take more definitive action when the emergency occurred.

A review of engine orders ahead showed a very clear pattern of activity for each group of subjects. Pilots gave almost twice as many orders as masters (62 versus 35). Not only were orders given more frequently by the pilots, but they tended to be larger as well ($\bar{x}$ engine orders for pilots equals 20.90 RPM, $\bar{x}$ engine orders for masters equals 16.40 RPM). Pilots also did not hesitate to use full engine RPM and then revert back to "zero" rather than 3/4, 1/2, or 1/4 speed in an attempt to control ownship after the failure.

The distribution of engine orders astern did not show any appreciable difference in the behavior of masters and pilots. For both groups, the greatest number of commands (over 55 percent) occurred directly after the failure, indicating a realistic response to the emergency.

The amount of rudder remaining, engine RPM remaining, and thruster remaining were summarized for all masters and pilots. These measures indicate the amount of rudder, RPMs, and thruster power available to the subject for emergency use. The amount of rudder remaining was calculated by subtracting the maximum available rudder (35°) from the average amount used, and then dividing the absolute value of this difference score by the maximum available rudder (35°). RPM and thruster remaining were calculated in a similar way, substituting the appropriate values for maximum available RPM and thruster. No differences in the performance of masters and pilots were found for these measures. (See Figure B-43.)

Leg 2 – 51° Turn – Training Objective: Negotiating a 51° Turn with Passing Ship Effects

Six performance measures were collected for this segment. The task of the subject was to maneuver ownship through a 51° turn while passing an outbound containership approaching the channel bend from the other direction. The actual track plots for all masters appear on the right-hand side of Figures C-1 through C-14 and for pilots in Figures C-15 through C-28. In these plots, both the channel boundaries and center trackline are shown, but the outbound tanker is not indicated. The track plots on the left of each chart represent Leg 3 and will be subsequently detailed.

a. CPA to Ship 3 – 51 Turn – (Outbound Containership) The average CPA for masters (x 487.3 feet) did not differ significantly from the average CPA for pilots (x 504.5 feet). In addition, the lower end of the pilots' 90 percent confidence interval as a cutoff yielded no significant differences in proportion of masters and pilots who achieved or did not achieve this criterion. The data, however, are included for reference in Figures C-29 and C-30.

b. 51 Turn – Maximum Swept Path The scores in this measure varied very little between masters and pilots (see Figures C-31 and C-32). A 90 percent confidence interval cutoff score did not result in significantly different proportions of masters and pilots who exceeded this score.

. 51 Turn – Average Swept Path The scores for average swept path for masters and pilots also did not differ significantly (see Figures C-33 and C-34). Therefore, no generalizations can be made about the relative performance of the two groups based on this measure.

d. 51 Turn – Maximum Ratio Swept Path This measure also did not yield any meaningful results. Figures C-35 and C-36 are a summary of the data.

51 Turn – Average Ratio Swept Path This measure yielded no statistically significant results. Figures C-37 and 38 show the means and standard deviations for both groups. A χ^2 test comparing the proportions of masters and pilots who achieved criterion based on a 90 percent confidence limit also proved nonsignificant.

51 Turn – Groundings An analysis of the number of groundings in this leg revealed that three masters and two pilots grounded ownship during the run. Because this difference is insignificant, little can be determined from this information.

In summary, all of the above measures proved insufficient to distinguish between the performance of masters and pilots. Therefore, within the context of this particular scenario these measures do not hold much promise as criteria for training.

Summary of Performance Measures in Leg 2, 51 Turn

Performance measures useful as training criteria:

- None

Performance measures not useful as training criteria

- CPA to outbound containership
- Maximum swept path
- Average swept path
- Maximum ratio swept path
- Average ratio swept path

Analysis of Bridge Activity in Leg 2, 51 Turn An examination of bridge behavior shows that subjects in both groups gave the most rudder orders about halfway through the first section of this leg. A secondary spurt at the end of this section and a tapering off in activity for the rest of the run was also evident (see Figures C-39, C-40, and C-41). These graphic illustrations show that both groups ordered almost an identical number of full right or full left rudder orders. However, pilots tended to give more "midships" orders than masters, especially during the middle third of the run (Figure C-40). No other distinct patterns of activity were recognizable in this leg.

Masters and pilots also did not show any differences in rudder, engine, and thruster percent remaining. Means of each measure are given in Figure C-42 and t tests of the data yielded no significant comparisons.

Leg 3 – 129 Turn – Training Objective: Negotiating a 129 Turn Around Shoal with Oncoming Traffic

Five performance measures were calculated for this leg and (with the exception of CPA to containership) were identical to the ones detailed in the anlaysis of Leg 2. The actual tracks for this leg are show on the left side of the plots in Figures C-1 through C-14 (masters) and Figures C-15 to C-28 (pilots).

a. 129 Turn – Maximum Ratio Swept Path This measure yielded meaningful results. The difference between the means of masters (x 7.03) and pilots (x 0.664) was significant ($p < 0.05$). (See Figure D-5.) A cutoff score based on the 90 percent confidence limits yielded ten pilots (of 14) and five masters (of 14) who exceeded this criterion. These proportions are significantly different (χ^2 = 3.59, $p < 0.05$) and indicate the potential use of this measure to differentiate performance of master and pilots. The frequency data are summarized and illustrated in Figures D-5 and D-6, respectively.

b. 129 Turn – Maximum Swept Path The results of this measure are summarized in Figure D 1. The mean maximum swept path for masters ($\bar{x}$ = 534 feet) is not statistically different from that of pilots ($\bar{x}$ = 514 feet). If the lower end of the pilot's 90 percent confidence interval (534.7 feet) is used as a criterion, 13 of 14 pilots and only 7 of 14 masters achieved this score. The difference between these proportions is significant (χ^2 = 4.38, $p < 0.025$) and is graphically shown in Figure D-2.

c. 129 Turn – Average Ratio Swept Path - An analysis of this measure shows that the difference between the means of both groups was not statistically significant (Figures D 7 and D 8). There were also no statistically significant differences between the proportions of pilots and masters who achieved a cutoff score derived from the 90 percent confidence interval.

d. 129 Turn – Average Swept Path – No significant differences between masters and pilots were found for this measure. The data for this leg, however, are shown for reference in Figures D-3 and D-4.

e. 129 Turn – Number of Groundings – In this leg, two pilots and three masters grounded. These data are insufficient to provide a basis for discriminating between the performance of masters and pilots.

Summary of Performance Measures for Leg 3, 129 Turn

Performance measures useful as training criteria:

- Maximum swept path
- Maximum ratio swept path

Performance measures not useful as training criteria:

- Average swept path
- Average ratio swept path

Analysis of Bridge Activity in Leg 3, 129 Turn – An analysis was made of both rudder and engine orders for this leg. The analysis included such factors as magnitude of response, time of response, position of ownship, and number of orders given. No distinguishable patterns of rudder and engine activity were found. Thus, it appears that the bridge behavior of masters and pilots is similar for this leg.

No difference between masters and pilots' percent remaining of rudder, engine, and thrusters was found. Details of these measures are given in Figure D 9.

Leg 4 – Propulsion Failure – Training Objective: Shiphandling in Response to Propulsion Failure in Vicinity of Bridge and Shoal

This leg investigated how masters and pilots responded to an emergency situation, that of propulsion failure. The two primary tasks to ownship were to avoid grounding on the shoal as the ship approached the bridge and to avoid colliding with the bridge itself. The track plots appear in Figures E-1 through E-14 for all masters and Figures E-15 through E-28 for all pilots.

a. Propulsion Failure – Safe Completion of Transit – Of 14 pilots tested, eight pilots did not ground on the shoal nor hit the bridge and, therefore, were considered to have safely completed the transit. However, of the 14 masters tested, only three completed the transit without a casualty. These proportions differ significantly ($\chi^2(1)$ = 3.74, $p < 0.10$) and support the adoption of this measure as a performance criterion.

b. Propulsion Failure – Grounding on Shoal – Of the 14 subjects in each group, a total of two pilots and five masters grounded on the shoal. A chi square analysis of these data does not yield significance ($\chi^2(1)$ = 1.71). Thus, the use of grounding on the shoal as a performance measure does not adequately discriminate shiphandling ability of masters and pilots during this specific emergency.

***c. Propulsion Failure* – Collisions with Bridge** – Of the subjects who did not ground on the shoal, six out of the remaining nine masters hit the bridge while four of the remaining 12 pilots hit the bridge. This difference is not significant ($\chi^2(1)$ = 2.29) and indicates that this particular measure does not appear to be useful as a performance criterion.

Summary of Leg 4, Propulsion Failure

Performance measures useful as training criteria.

- Safe completion of transit

Performance measures not useful as training criteria:

- Groundings on shoal
- Collisions with bridge

Summary of Bridge Activity, Propulsion Failure While there was virtually no difference in the total number of rudder orders given, it was apparent that masters tended to give more rudder orders before the failure than pilots. After the failure, pilots tended to give more orders than masters. An examination of the action taken directly after the propulsion failure indicates some interesting differences in strategy. In terms of rudder use, pilots revert back to "midships" more frequently than do masters in recovering from the failure, and a higher percentage of pilots than masters called for full thrusters. It appears that pilots, reacting to the failure, prefer to use the thruster rather than the rudder to control ownship. Masters tend to rely on both in maneuvering the vessel in this situation.

The percent remaining of rudder, engine, and thruster for masters and pilots did not differ significantly between these groups. Details are reported in Figure E-29.

2.6 DISCUSSION OF RESULTS AND CONCLUSIONS

The harbor approach leg (Leg A) emerged as the all-around best discriminator between expert shiphandlers (pilots) and relatively inexperienced shiphandlers (chief mates upgrading to masters).

The fact that 13 pilots and only six masters recognized that the turn buoy used for harbor approach was off station suggests that pilots are more attentive to environmental cues. Since none of the pilots belonged to the Sandy Hook Pilot Association, they could not have relied on local knowledge to notice the off station buoy. (Port XYZ was a modification of New York Harbor.) Rather, one can infer that the expert shiphandler pays close attention to publications such as notices to mariners and relies on more than one indicator of position. A simulator training program can use the recognition of an off station buoy as a valid training objective. A successful training program should show greater attention to navigational aids after training.

The harbor approach leg also yielded data indicating that expert shiphandlers are more consistent and accurate at trackkeeping compared to relatively inexperienced shiphandlers. The mean and maximum deviations off the centerline, as well as average trackline, emerged as sensitive measures of shiphandling proficiency.

Every measure of performance applied to the harbor approach leg yielded differences between pilots and masters and yielded a criterion score which successfully discriminated between these groups. These criterion scores can only be applied to the specific scenario used in Leg A. However, one can expect that when graduates of other simulator training programs are placed in this harbor approach scenario, their performance can be compared to the standards established through the Phase 3 research.

In Leg 1, a rudder failure occurred as ownship passed by three anchored ships. The position of the rudder was stuck in a hard left position. Only through the proper use of engine and thrusters could ownship keep from colliding with either the anchored ships or the piers. Four pilots and one master eventually collided with an anchored ship, while no pilots and two masters collided with the piers. Whether an average of three to four collisions for every 14 rudder failure scenarios can be considered a "good" or "bad" record is not known. These data may simply reflect a reality that, given this scenario in the real world, 28 percent of the time a collision would result. Thus, the event of a collision failed to distinguish between pilots' and masters' emergency shiphandling abilities. While these results are initially surprising, a closer look at the subjects provides an explanation. The pilots were selected by their associations for their excellent records as local shiphandlers. However, the degree to which their expertise was based on local knowledge and the degree to which it was based on raw shiphandling ability was not known. Therefore, the pilots who collided may, in fact, be superior shiphandlers in their own areas, but this superiority does not completely transfer to a new environment. Likewise, one would have naively expected more than just three masters to have collided. However, masters were not selected specifically for their lack of proficiency in shiphandling, rather, they were selected for the length of time they held their licenses. Some of the masters may actually have been quite proficient at shiphandling, thus improving the overall performance of the masters as a group.

The best measure of expertise in emergency shiphandling was the amount of time it took a subject to reduce ownship's speed over the ground to less than 2 knots after the rudder failure occurred. Since the thrusters needed to gain control after the rudder failure were maximally effective at lower speeds, the quickness with which a subject could reduce the speed of ownship was considered a relevant measure of emergency shiphandling. The pilots and masters differed significantly with respect to this measure, and the cutoff score derived from this measure successfully discriminated between experts and novices.

In conclusion, proficiency in emergency shiphandling in response to a rudder failure in confined waters can be effectively gauged using the time it takes to reduce ownship's speed as a *performance measure*.

Shiphandling through a turn was examined using a 51° turn with passing ship effects in Leg 2 and a 129° precision turn in Leg 3. The number of groundings experienced by pilots and masters did not differ in these legs. This lack of difference is casualties is similar to that reported in Leg 1 and tends to confirm the explanation provided in the discussion of that leg.

Overall, the 51° turn did not yield differences in performance between masters and pilots. This may be due to a poor selection of performance measures (i.e., insensitive to differences in abilities), to poor scenario design (i.e., not sufficiently difficult to extract differences in ability), or to an inaccurate assumption that proficient shiphandling is necessary to properly execute a 51° turn with passing ship effects. The latter explanation (i.e., inaccurate assumptions) is probably not the case, since three masters and two pilots grounded ownship during the scenario, indicating that at least a modest amount of shiphandling ability is necessary to negotiate the 51° turn.

The more precise and difficult 129° turn of Leg 3 was a much better discriminator of shiphandling ability. Both maximum ratio swept path and maximum swept path emerged as successful discriminators of shiphandling proficiency. The cutoff scores obtained through the analysis of the data should serve as useful standards of simulator performance.

The approach to a railroad bridge in the vicinity of a shoal, followed by a propulsion failure, constituted the emergency shiphandling scenario of Leg 4. Five masters and two pilots grounded on the shoal. Six of the remaining nine masters and four of the remaining 12 pilots proceeded to hit the railroad bridge. While these differences were not statistically significant, they indicate a definite trend in the data. The best discrimination of emergency shiphandling ability in this particular scenario was the number of subjects who successfully completed the transit with no casualties. Eight of the pilots and only three of the masters emerged unscathed. This measure is a statistically valid discriminator which should prove useful in establishing performance standards.

In summary, the Phase 3 research was designed to establish performance standards for simulator training of chief mates upgrading to masters. Five different scenarios incorporating numerous training objectives were presented to pilots (expert shiphandlers) and masters (potential trainees) and their shiphandling abilities were measured. Four of the five scenarios yielded statistically valid performance standards. The methodology and results of the research are reported in detail in the text and appendices.

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APPENDIX A

PERFORMANCE MEASURES APPENDICES

LEG A – HARBOR APPROACH

TRAINING OBJECTIVE – SHIPHANDLING IN HARBOR APPROACH

LIST OF ILLUSTRATIONS

Number	
A-1 to A-14	Track Plots, Masters, Leg A, Harbor Approach
A-15 to A-28	Track Plots, Pilots, Leg A, Harbor Approach
A-29	Summary of Data and Contingency Table, Mean Deviation (in feet) Off Centerline, Leg A, Harbor Approach
A-30	Frequency Distribution and Confidence Interval, Mean Deviation (in feet) Off Centerline, Leg A, Harbor Approach
A-31	Summary of Data and Contingency Table, Maximum Deviation (in feet) Off Centerline, Leg A, Harbor Approach
A-32	Frequency Distribution and Confidence Interval, Maximum Deviation (in feet) Off Centerline, Leg A, Harbor Approach
A-33	Summary of Data and Contingency Table, Mean Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach
A-34	Frequency Distribution and Confidence Interval, Mean Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach
A-35	Summary of Data and Contingency Table, Maximum Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach
A-36	Frequency Distribution and Confidence Interval, Maximum Deviation (in feet) Off Averge Trackline, Leg A, Harbor Approach

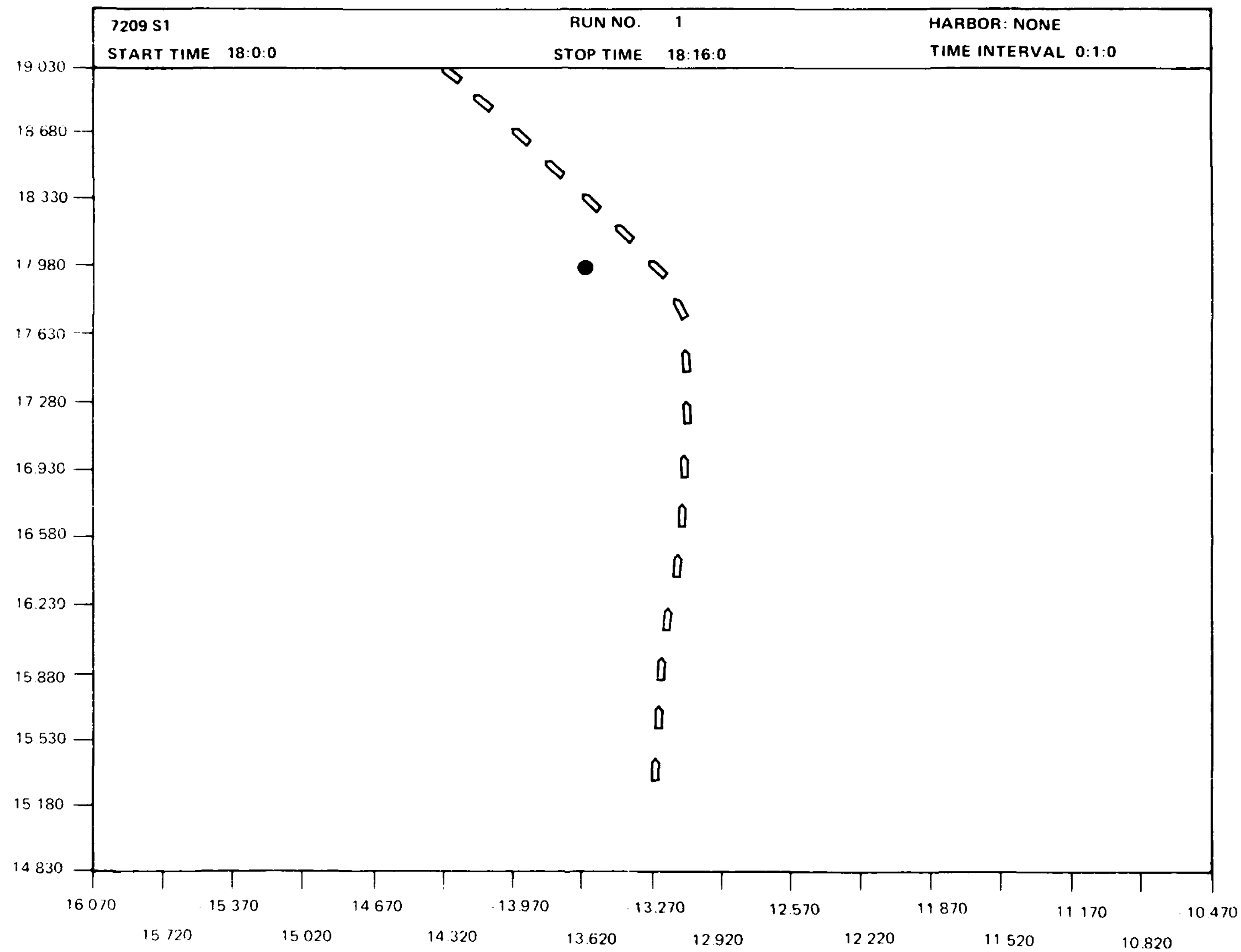

Figure A-1. Track Plots, Masters, Leg A, Harbor Approach

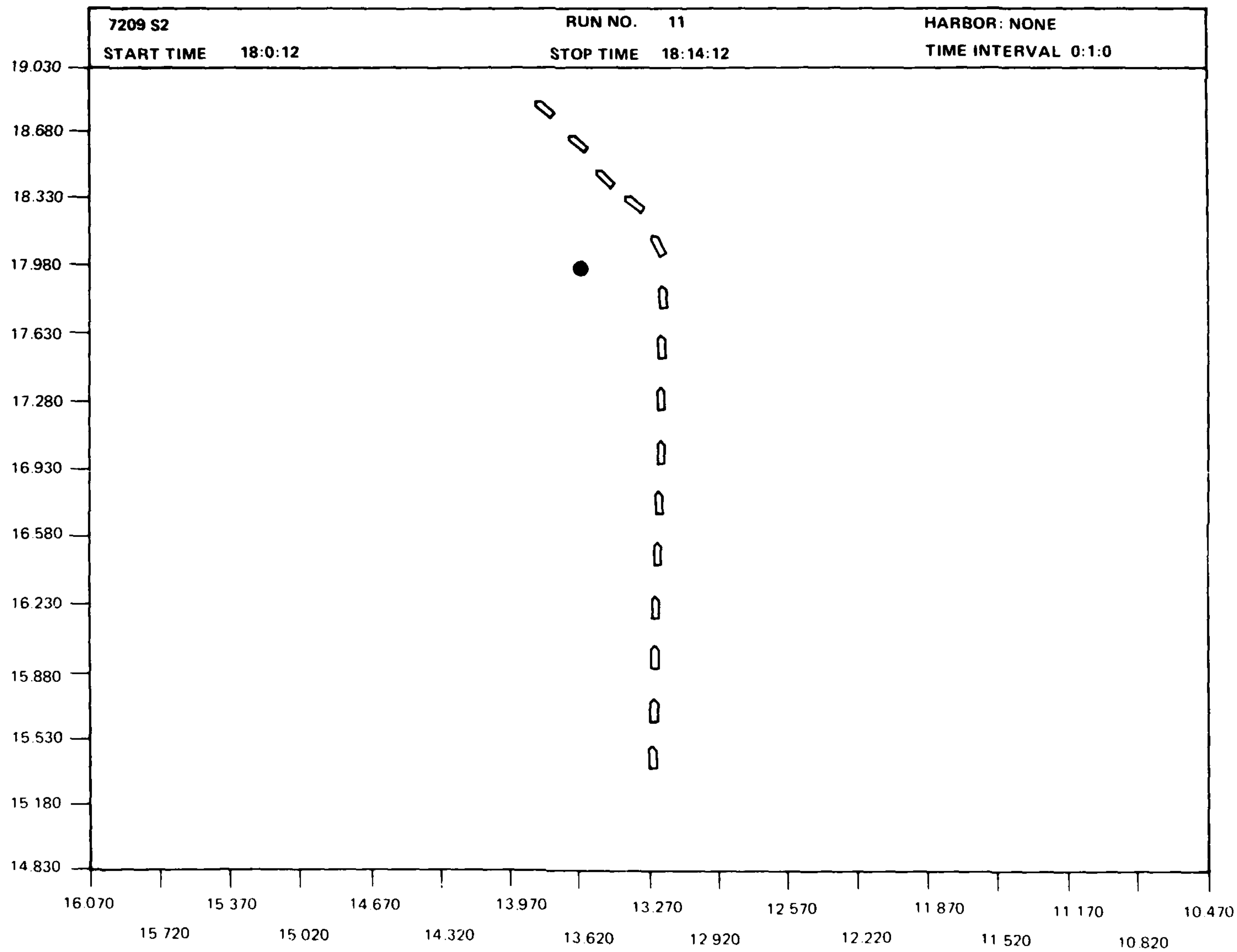

Figure A-2. Track Plots, Masters, Leg A, Harbor Approach

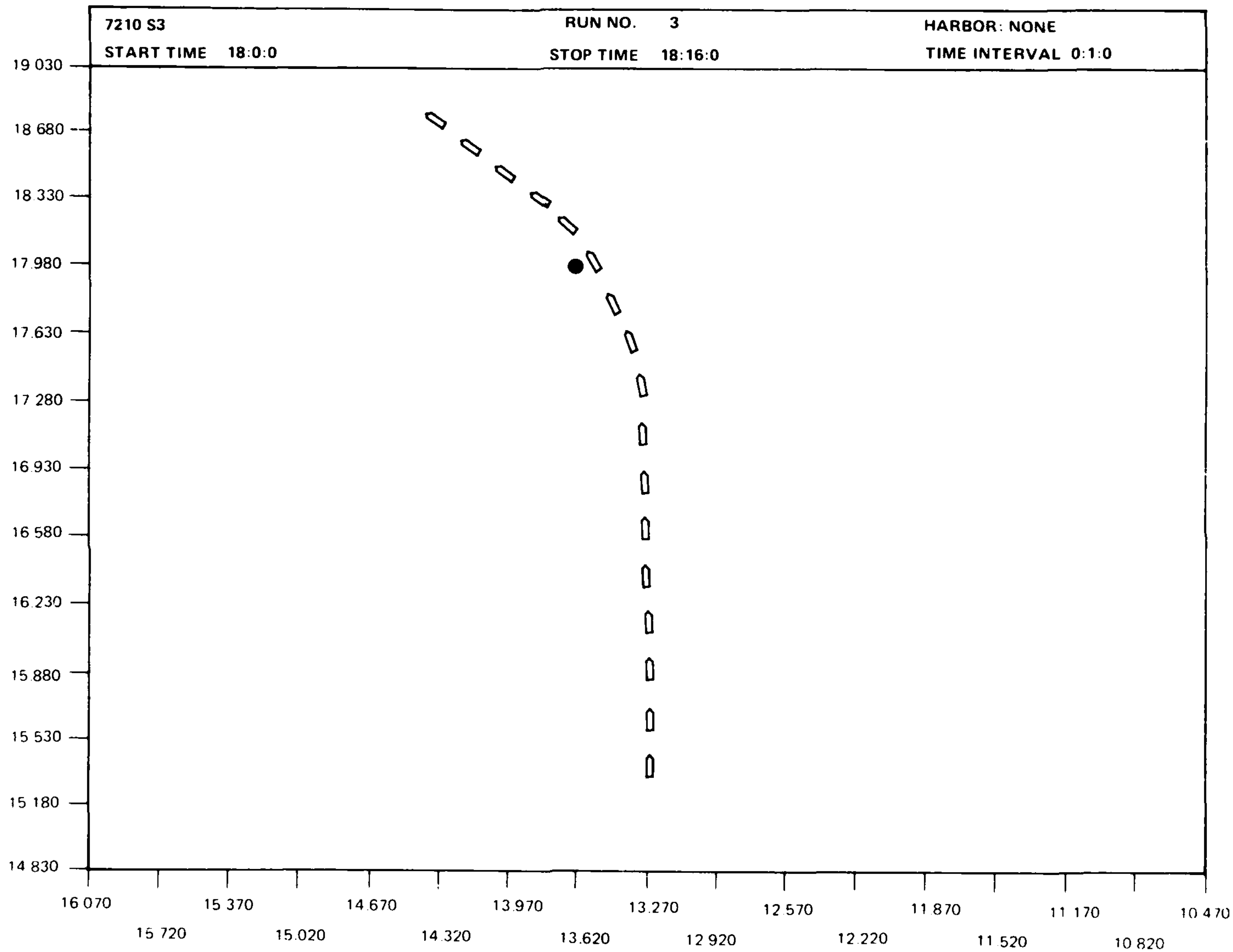

Figure A-3. Track Plots, Masters, Leg A, Harbor Approach

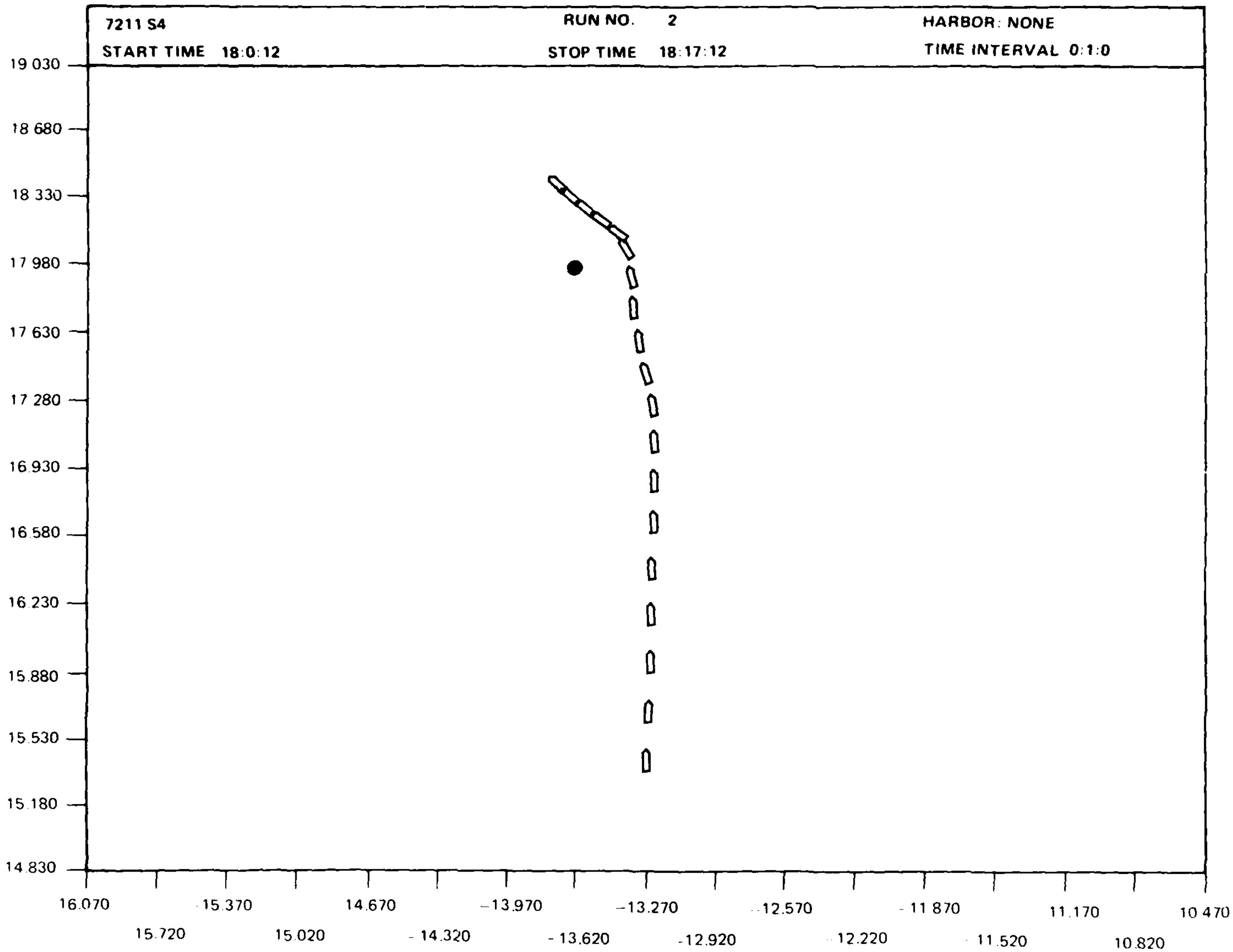

Figure A-4. Track Plots, Masters, Leg A, Harbor Approach

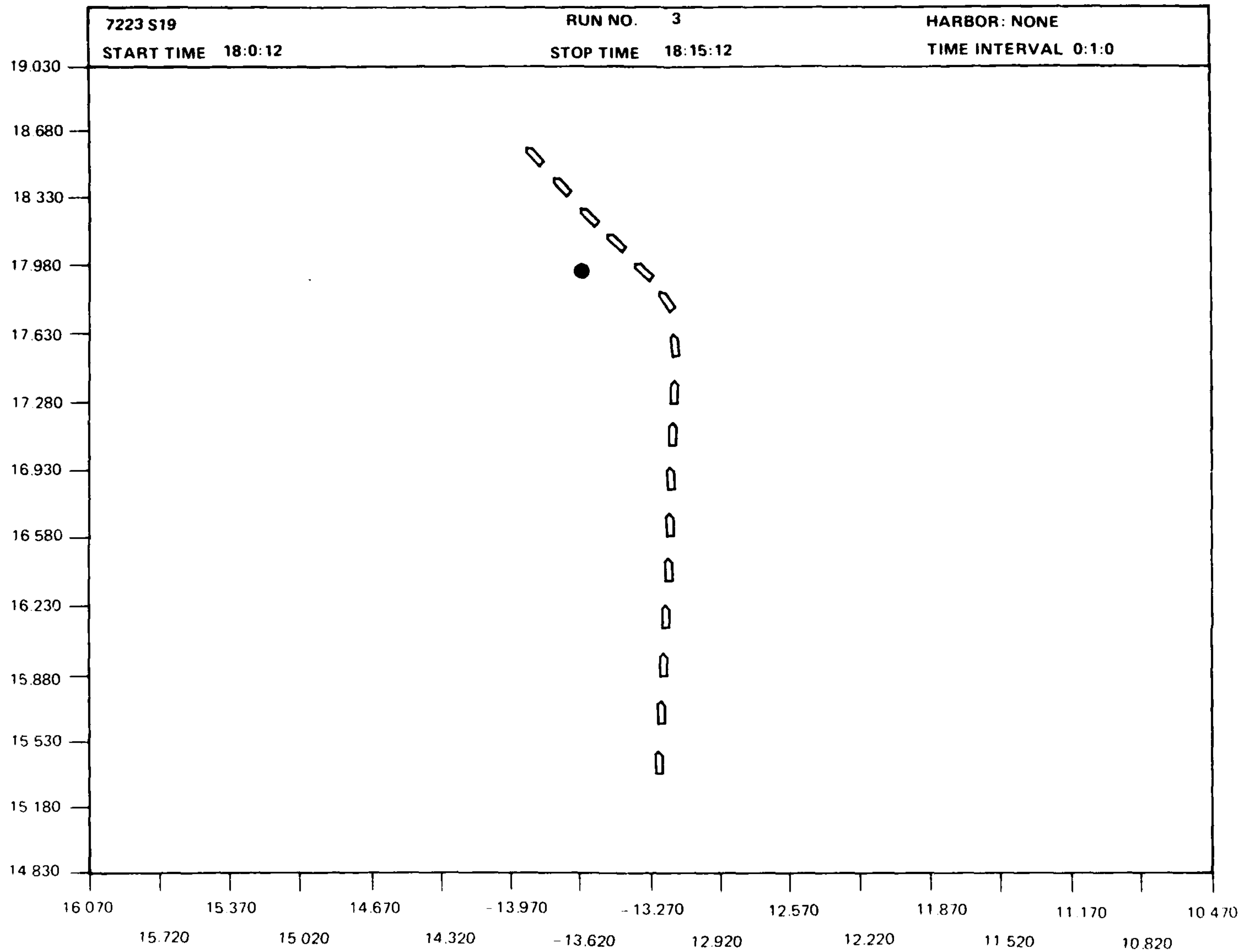

Figure A-5. Track Plots, Masters, Leg A, Harbor Approach

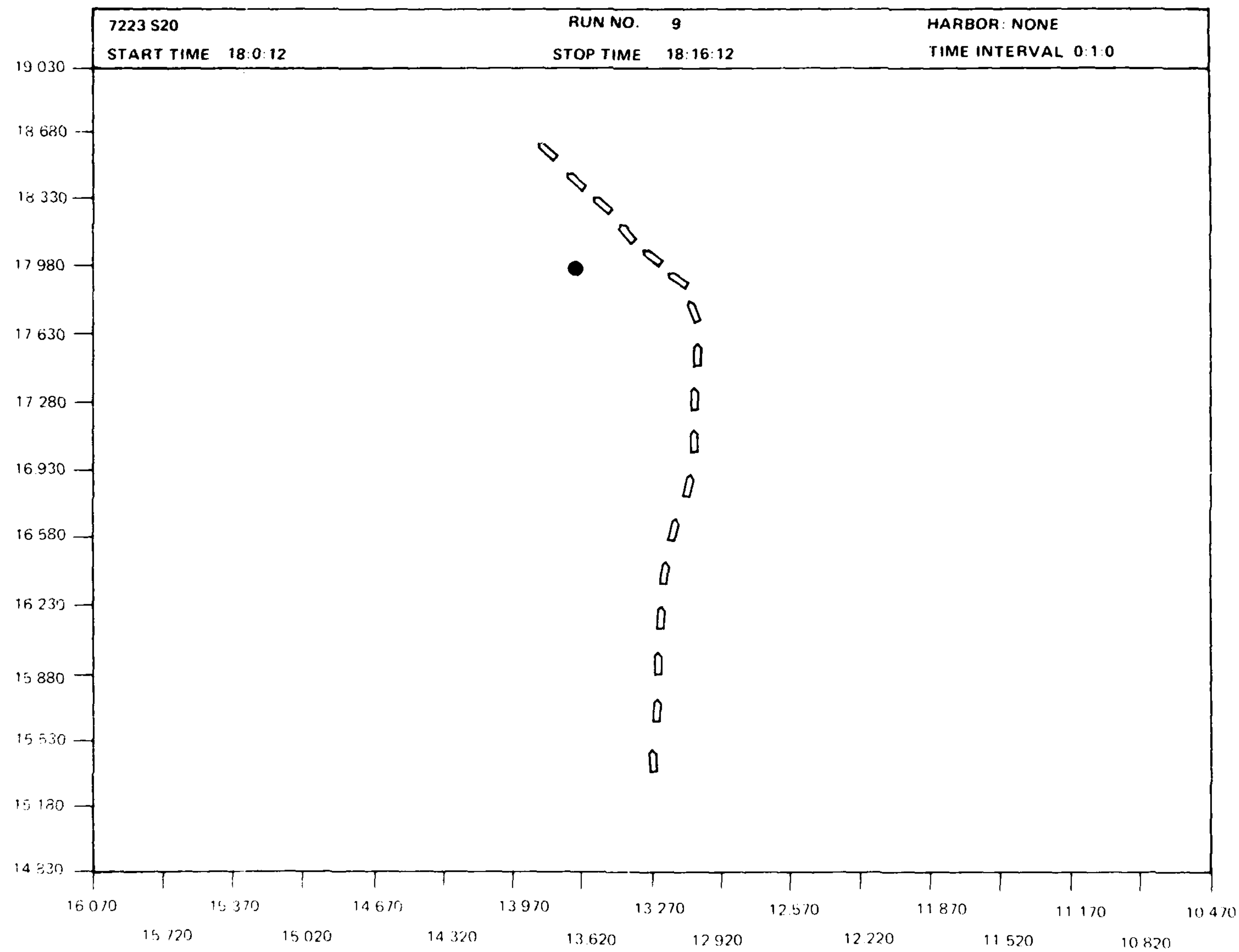

Figure A-6. Track Plots, Masters, Leg A, Harbor Approach

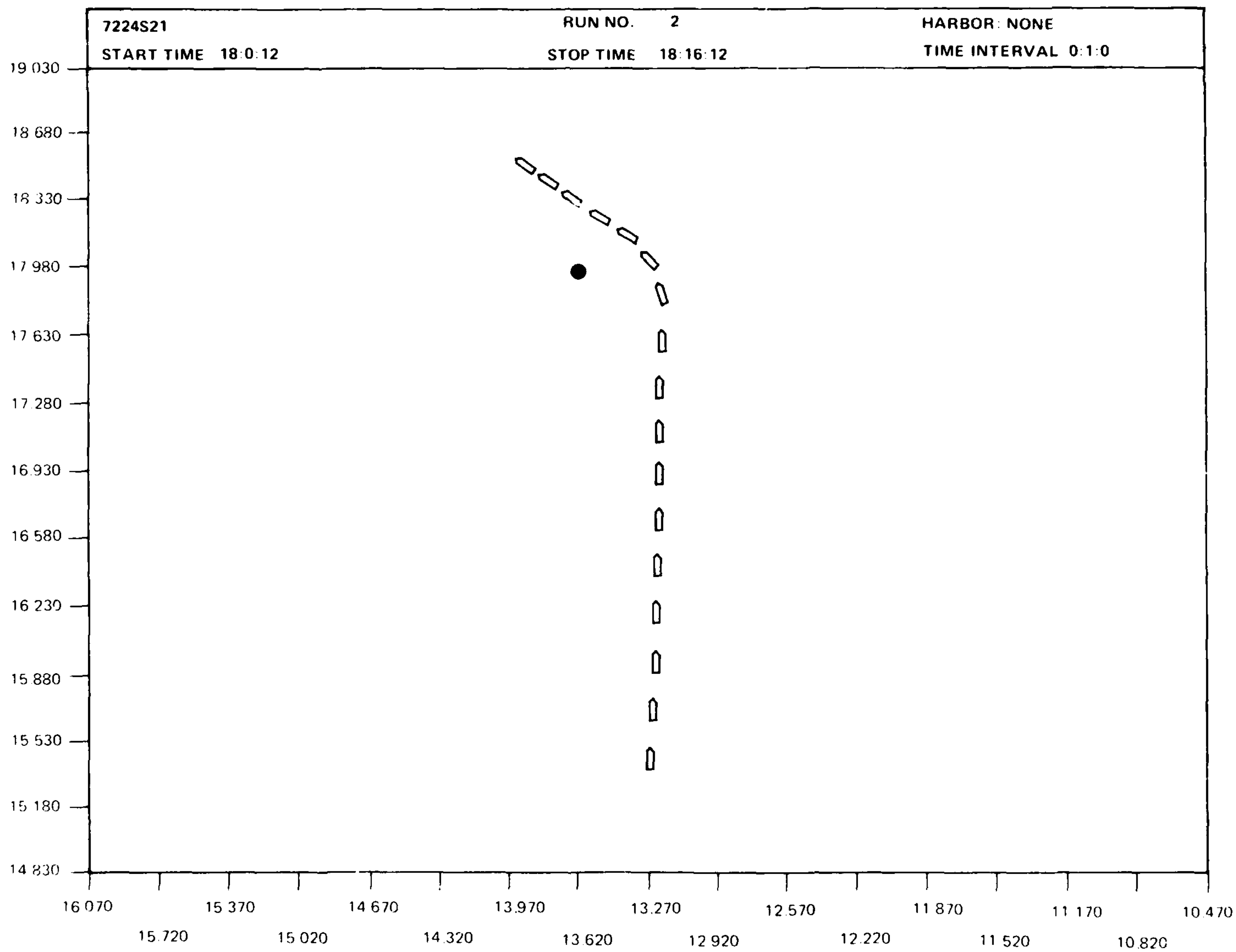

Figure A-7. Track Plots, Masters, Leg A, Harbor Approach

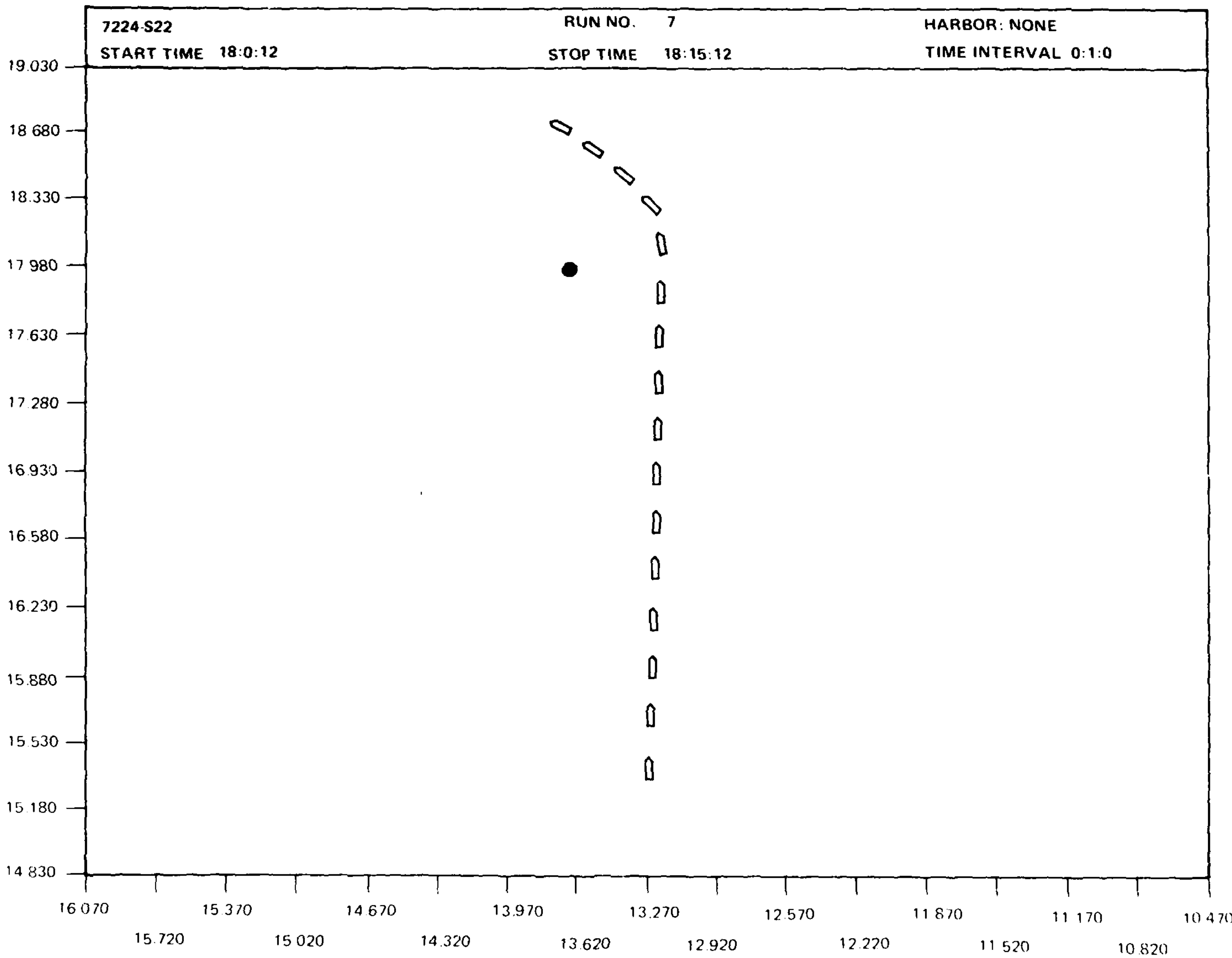

Figure A-8. Track Plots, Masters, Leg A, Harbor Approach

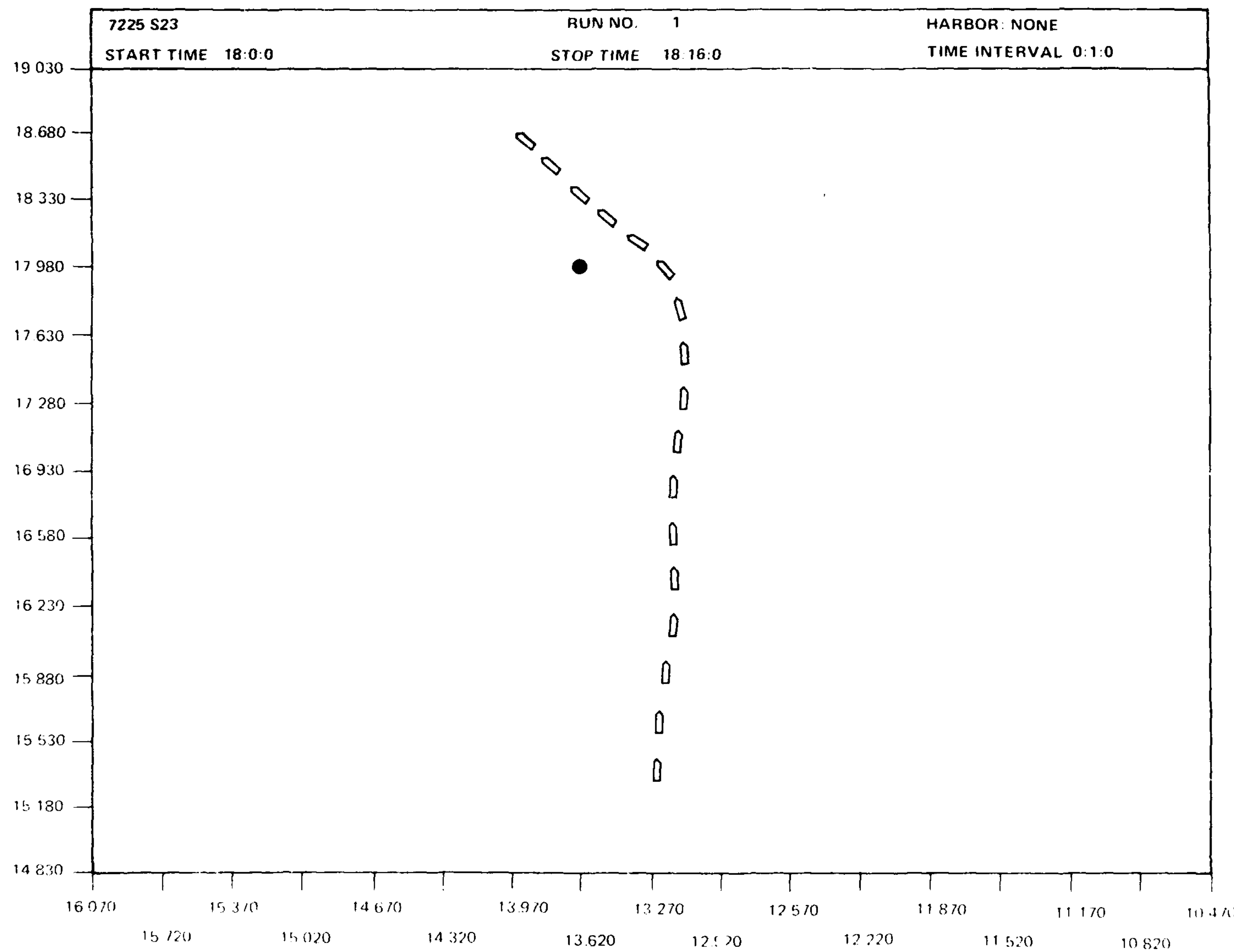

Figure A-9. Track Plots, Masters, Leg A, Harbor Approach

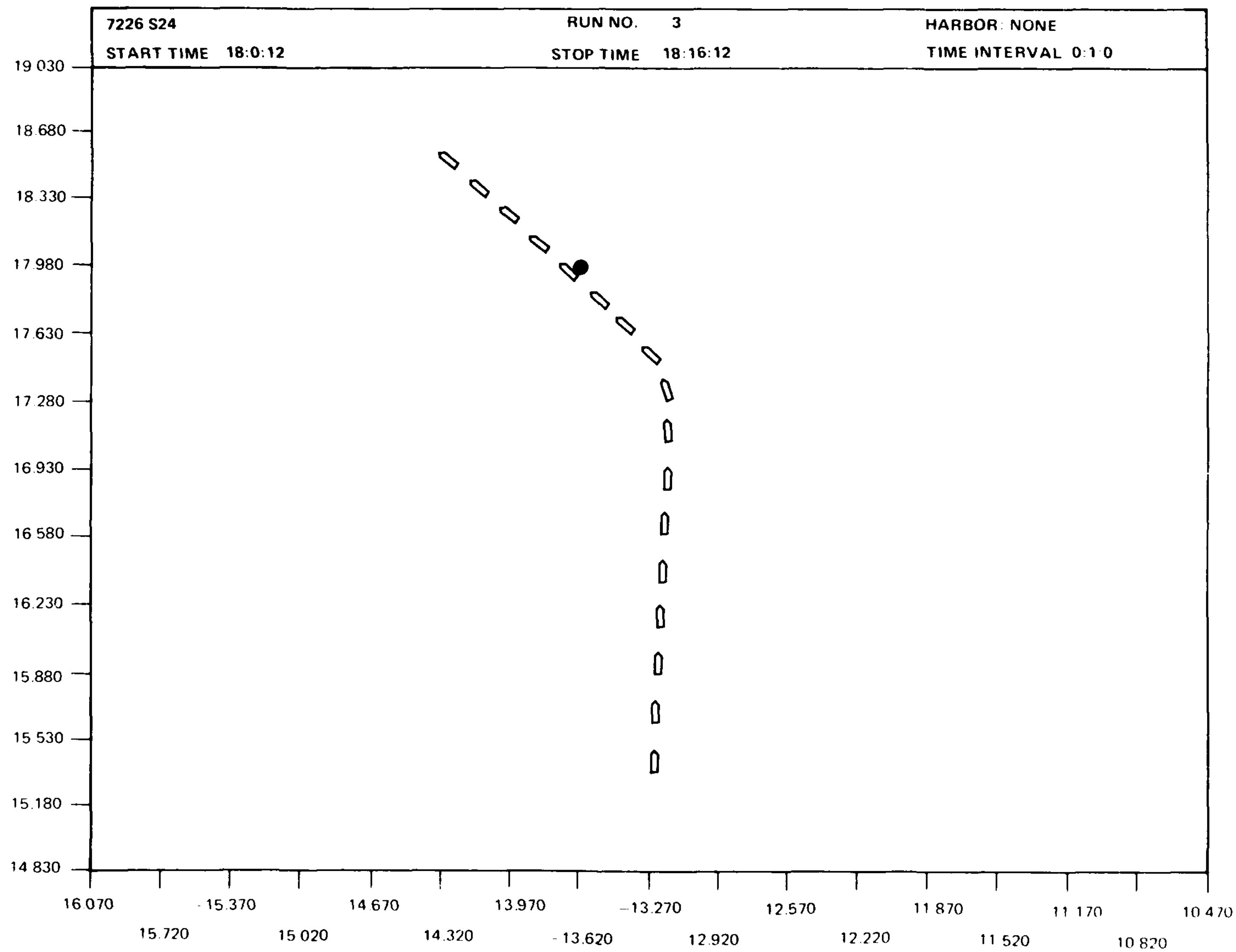

Figure A-10. Track Plots, Masters, Leg A, Harbor Approach

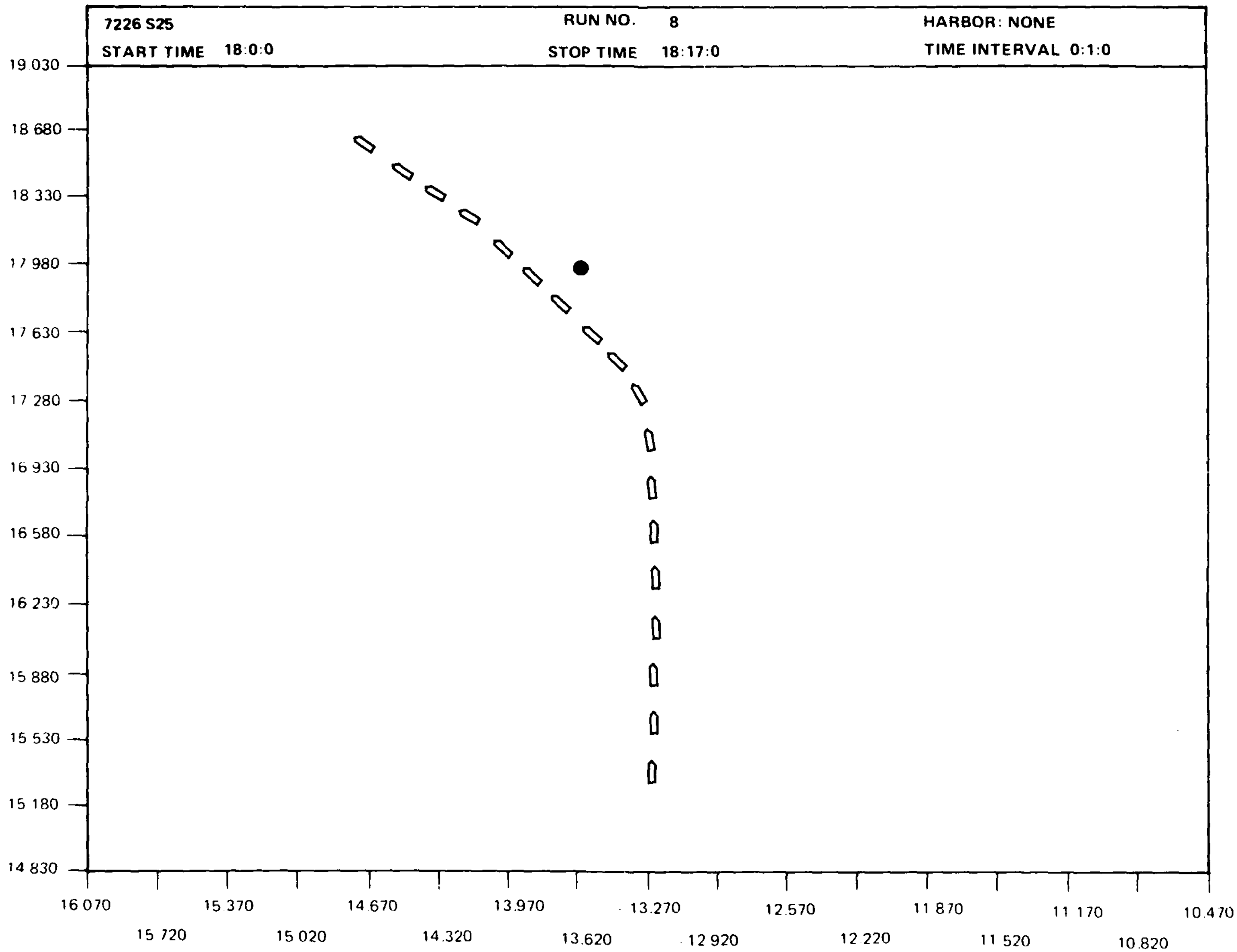

Figure A-11. Track Plots, Masters, Leg A, Harbor Approach

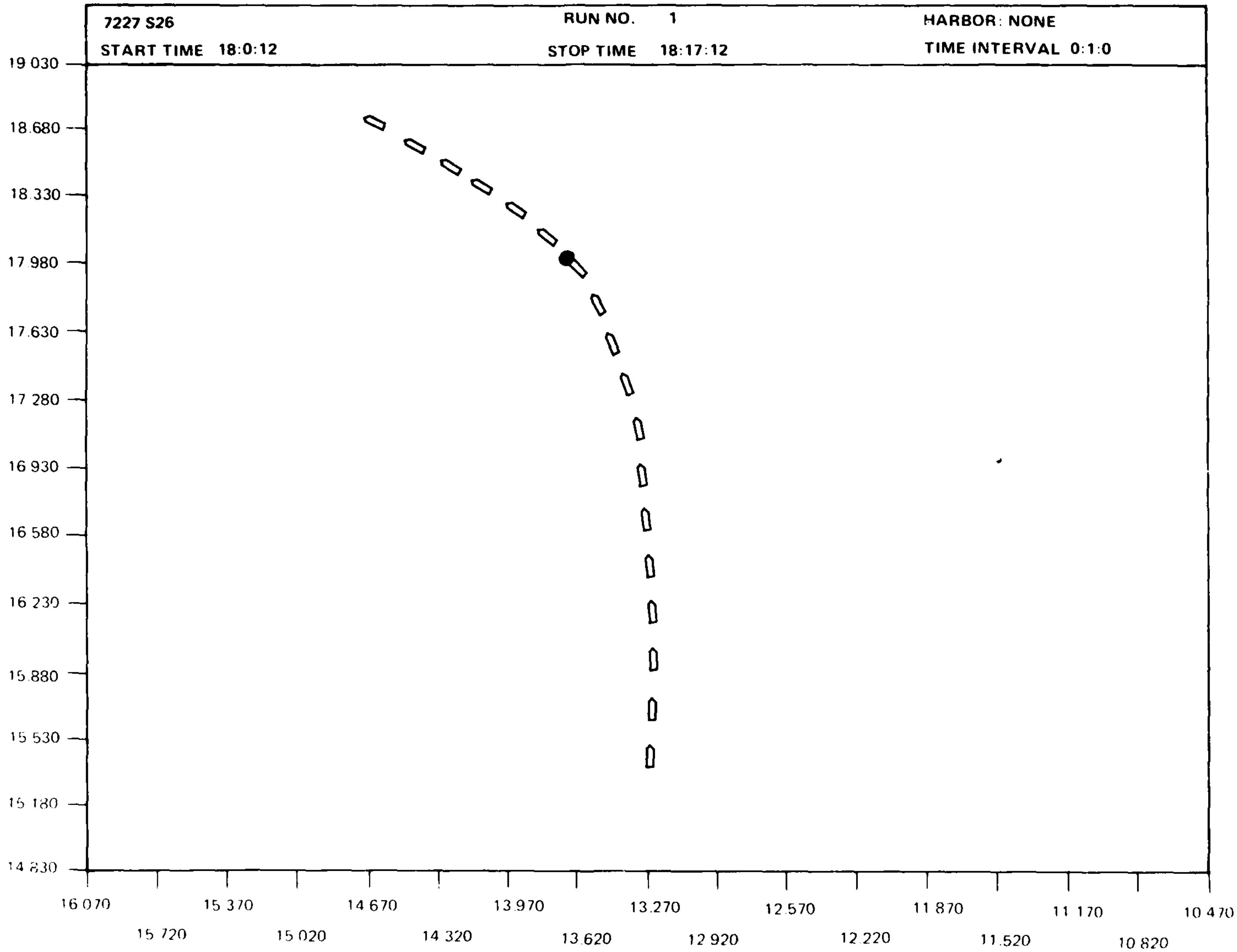

Figure A-12. Track Plots, Masters, Leg A, Harbor Approach

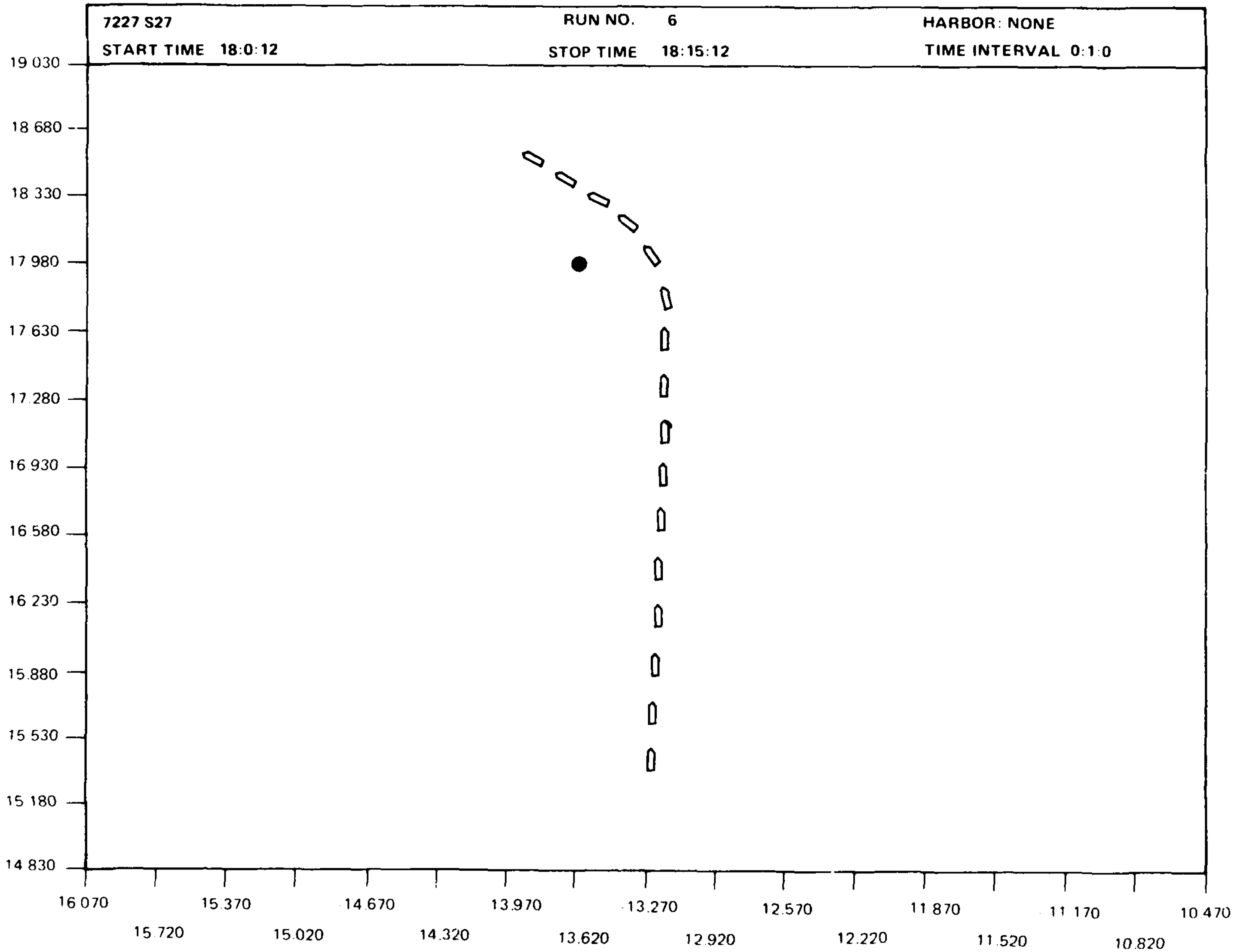

Figure A-13. Track Plots, Masters, Leg A, Harbor Approach

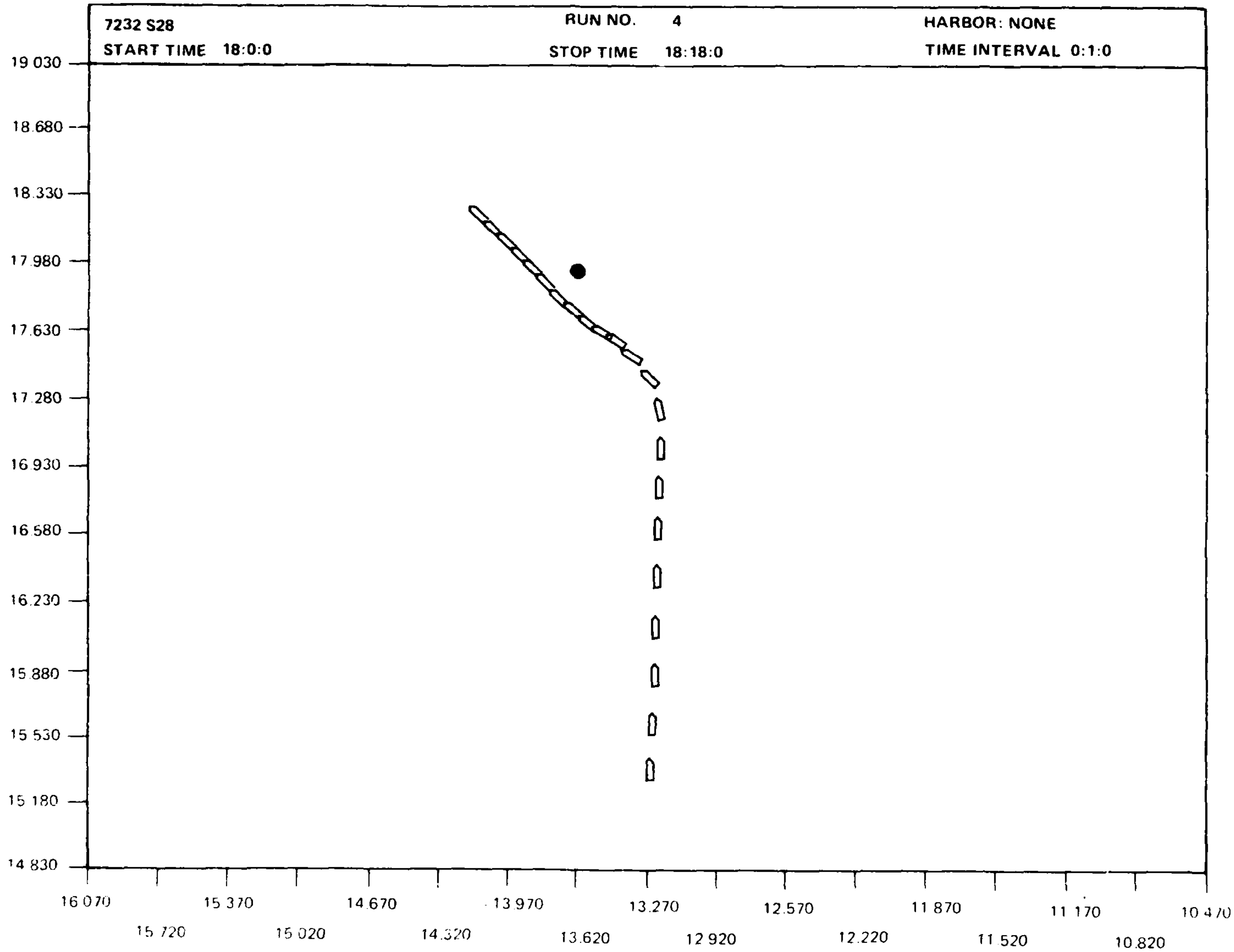

Figure A-14. Track Plots, Masters, Leg A, Harbor Approach

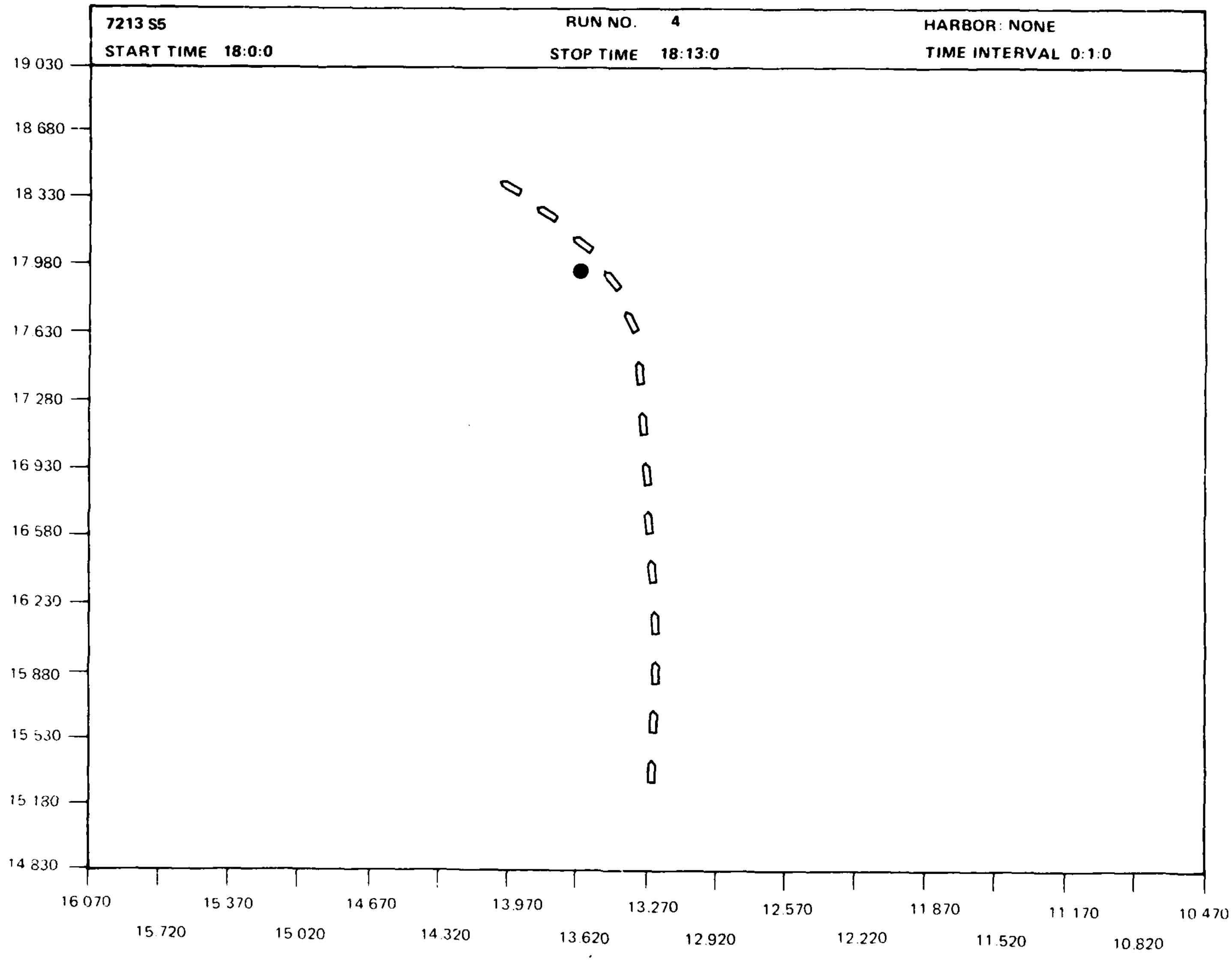

Figure A-15. Track Plots, Pilots, Leg A, Harbor Approach

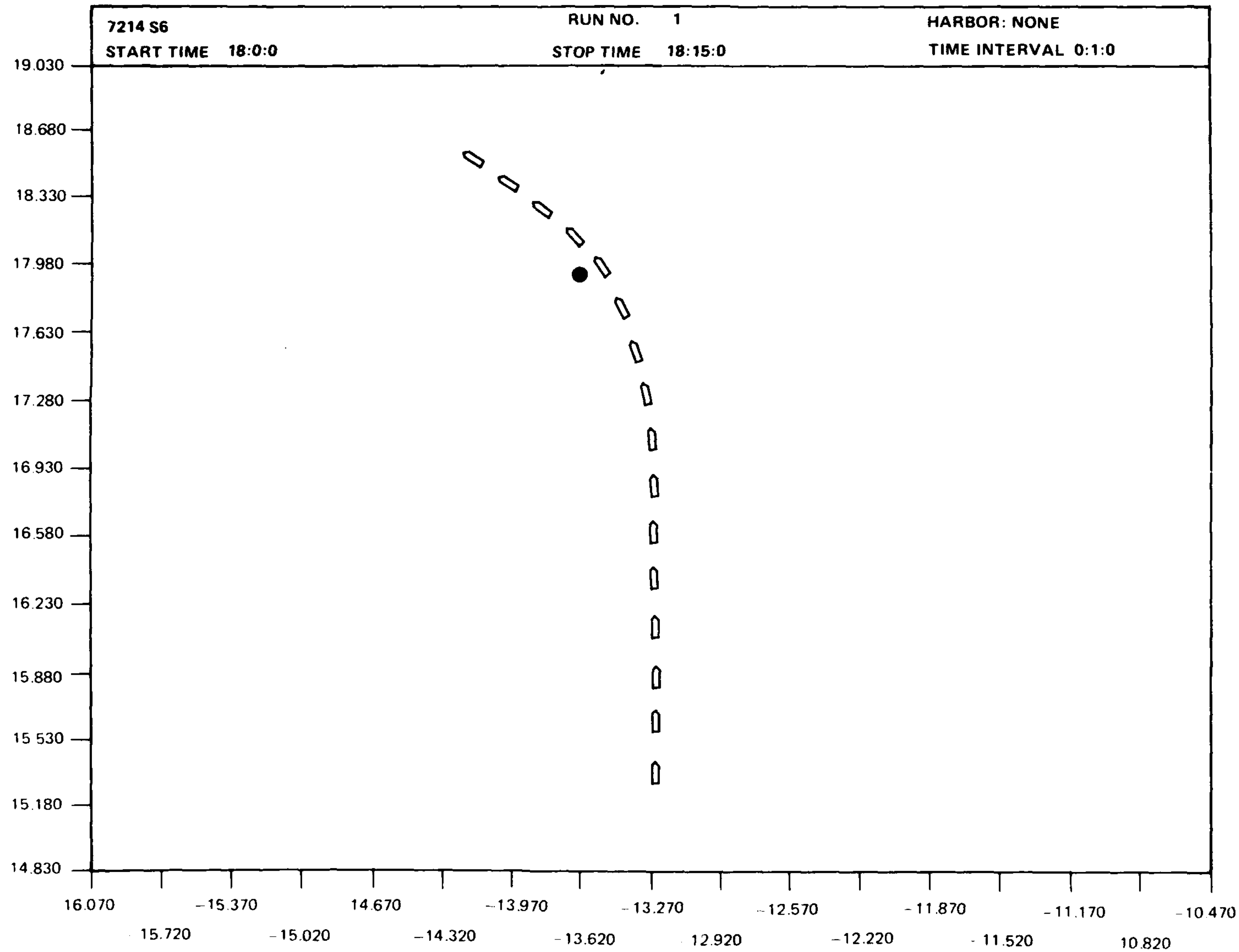

Figure A-16. Track Plots, Pilots, Leg A, Harbor Approach

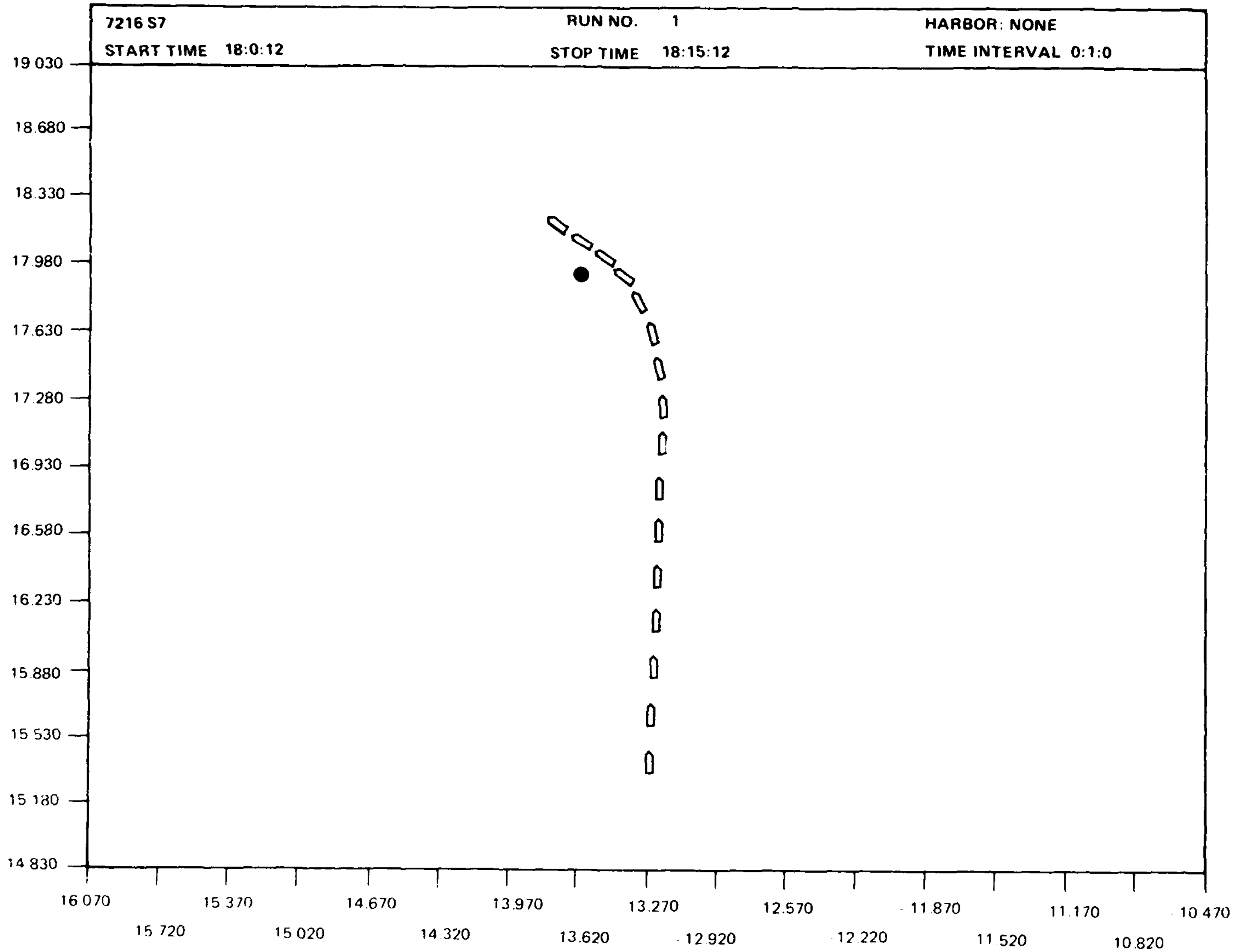

Figure A-17. Track Plots, Pilots, Leg A, Harbor Approach

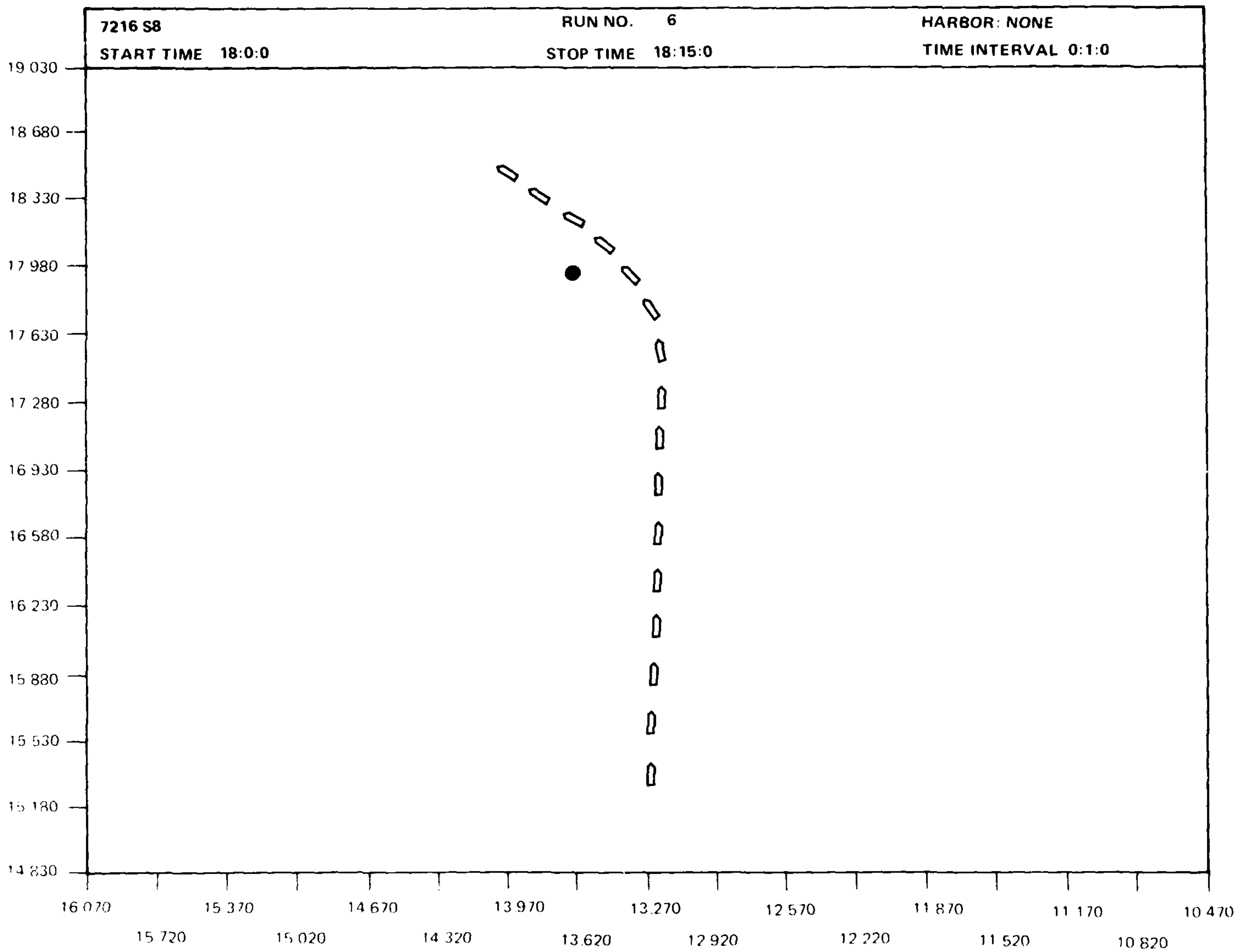

Figure A-18. Track Plots, Pilots, Leg A, Harbor Approach

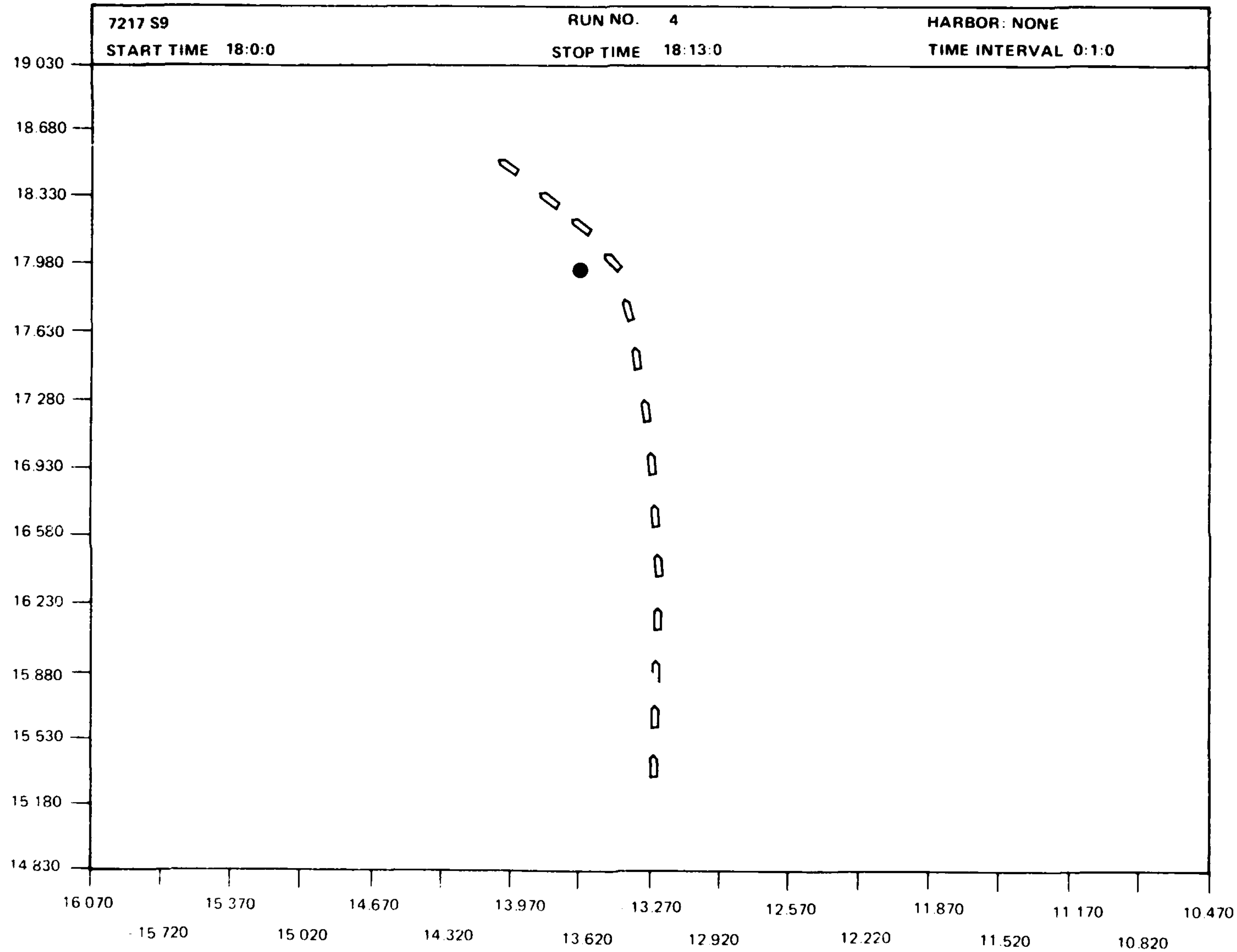

Figure A-19. Track Plots, Pilots, Leg A, Harbor Approach

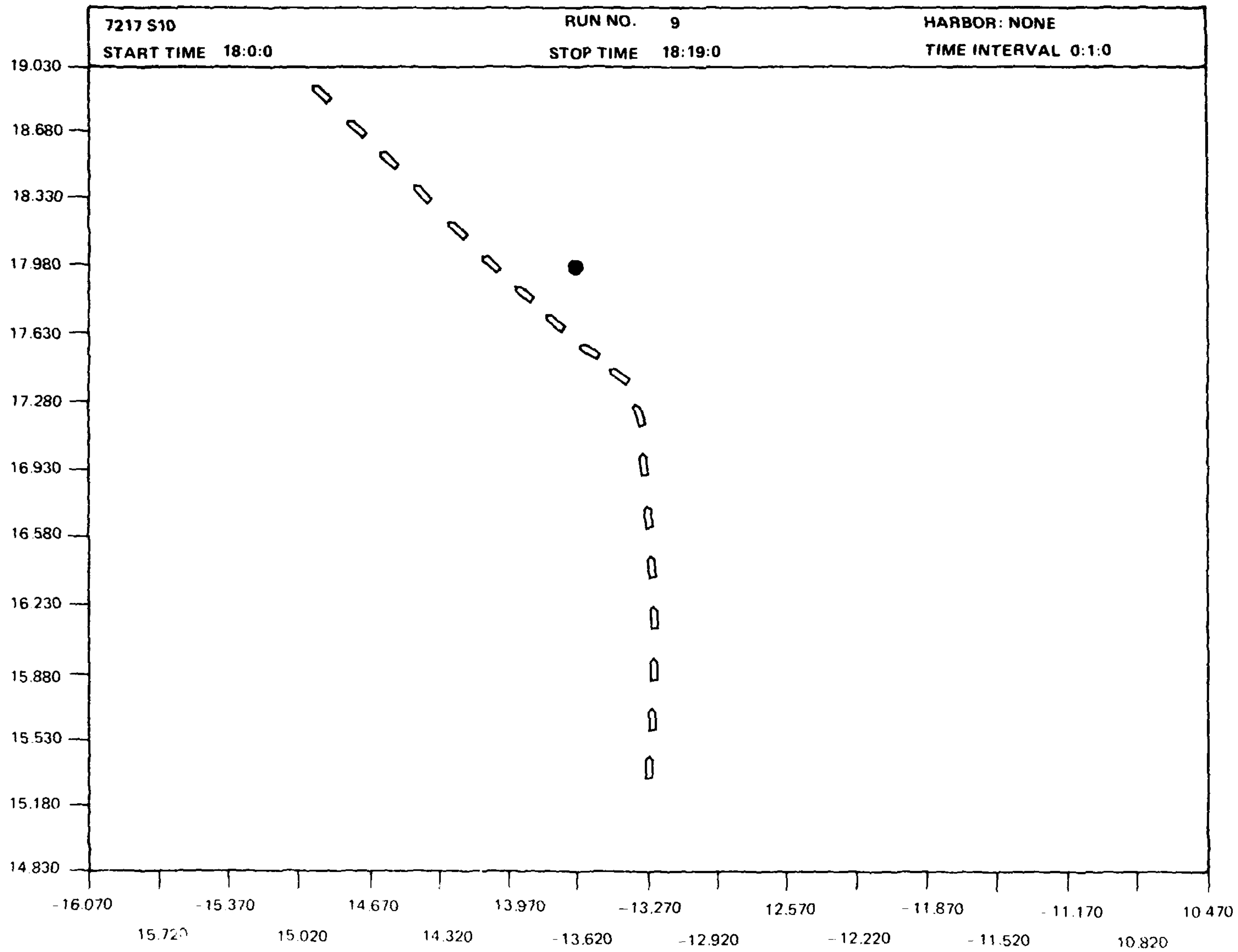

Figure A-20. Track Plots, Pilots, Leg A, Harbor Approach

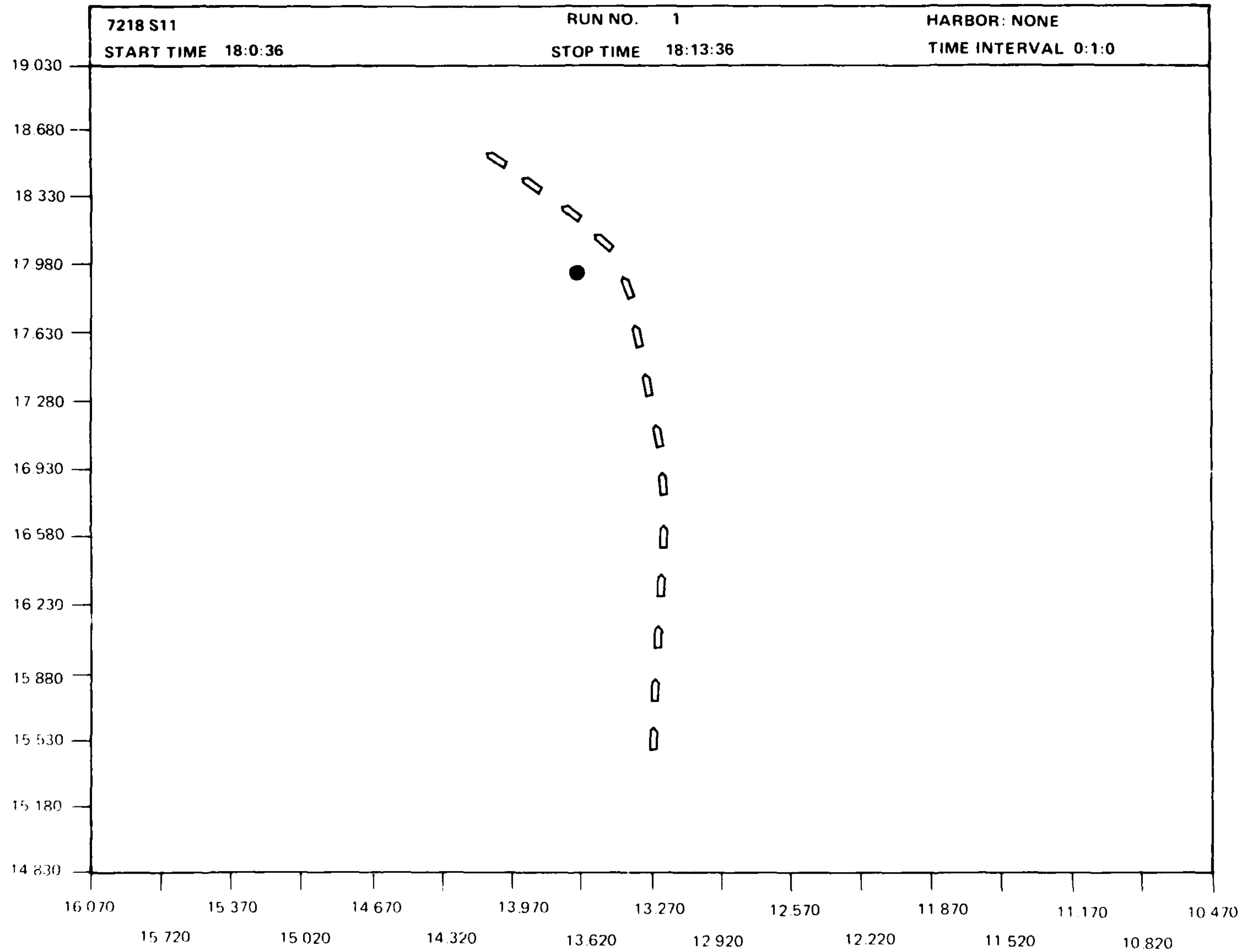

Figure A-21. Track Plots, Pilots, Leg A, Harbor Approach

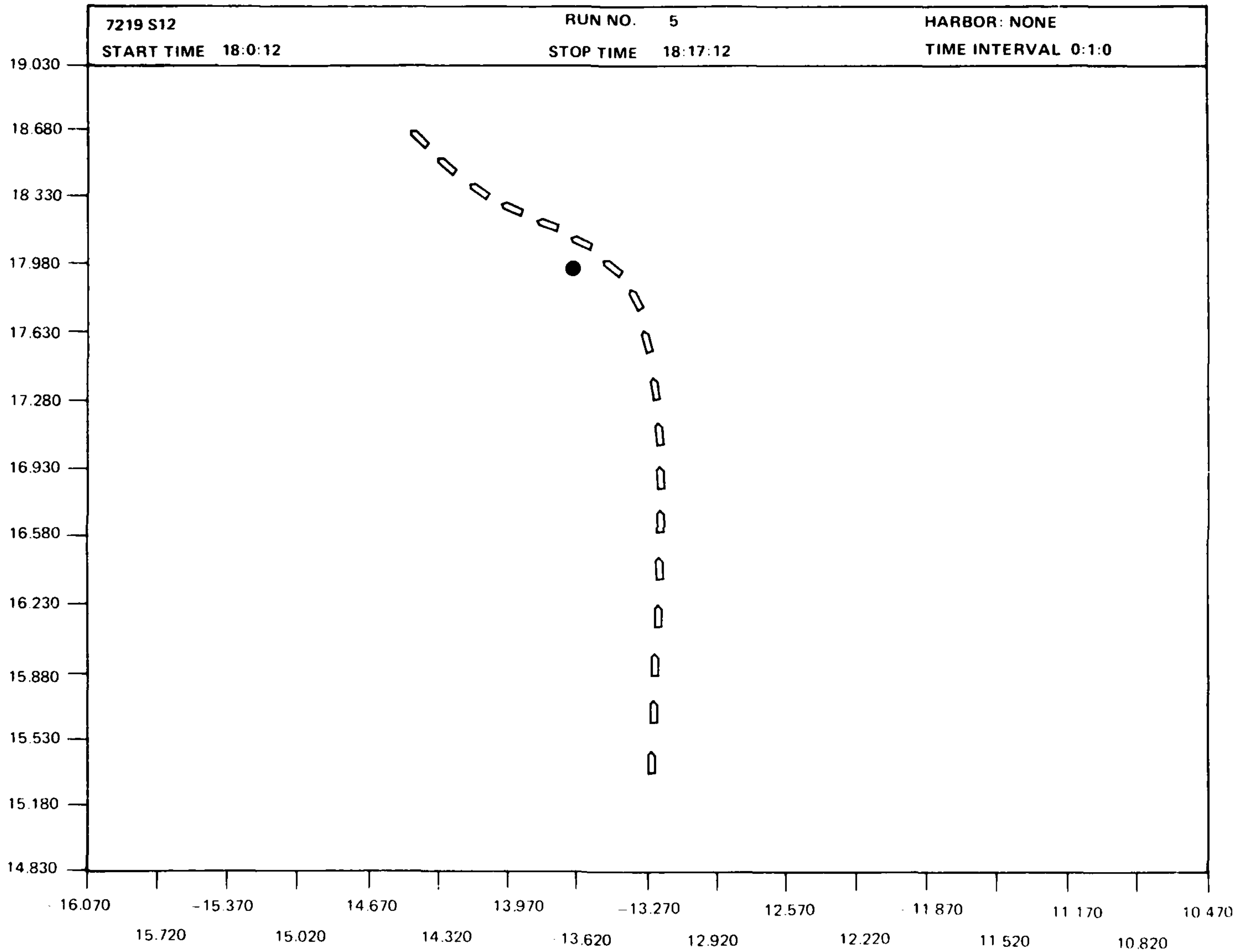

Figure A-22. Track Plots, Pilots, Leg A, Harbor Approach

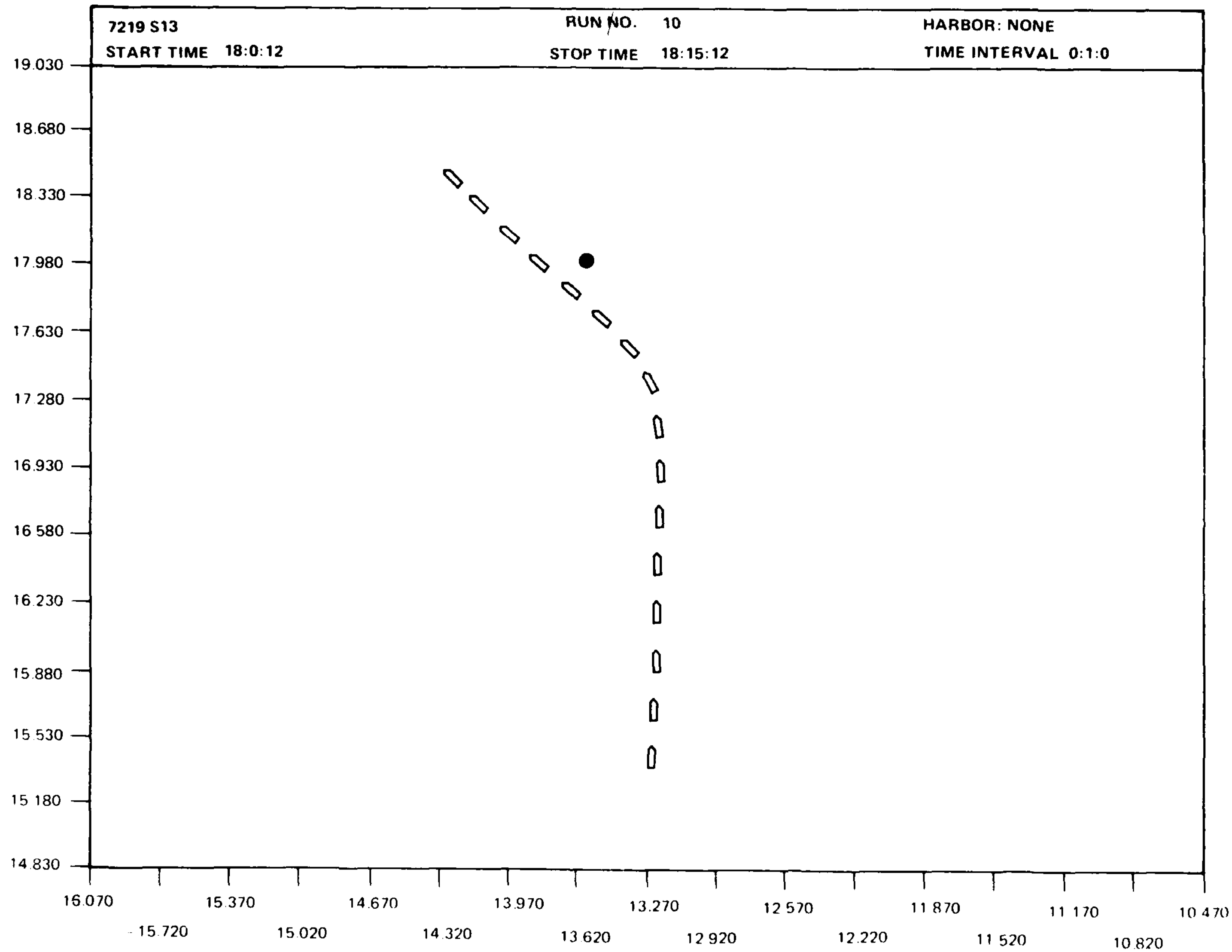

Figure A-23. Track Plots, Pilots, Leg A, Harbor Approach

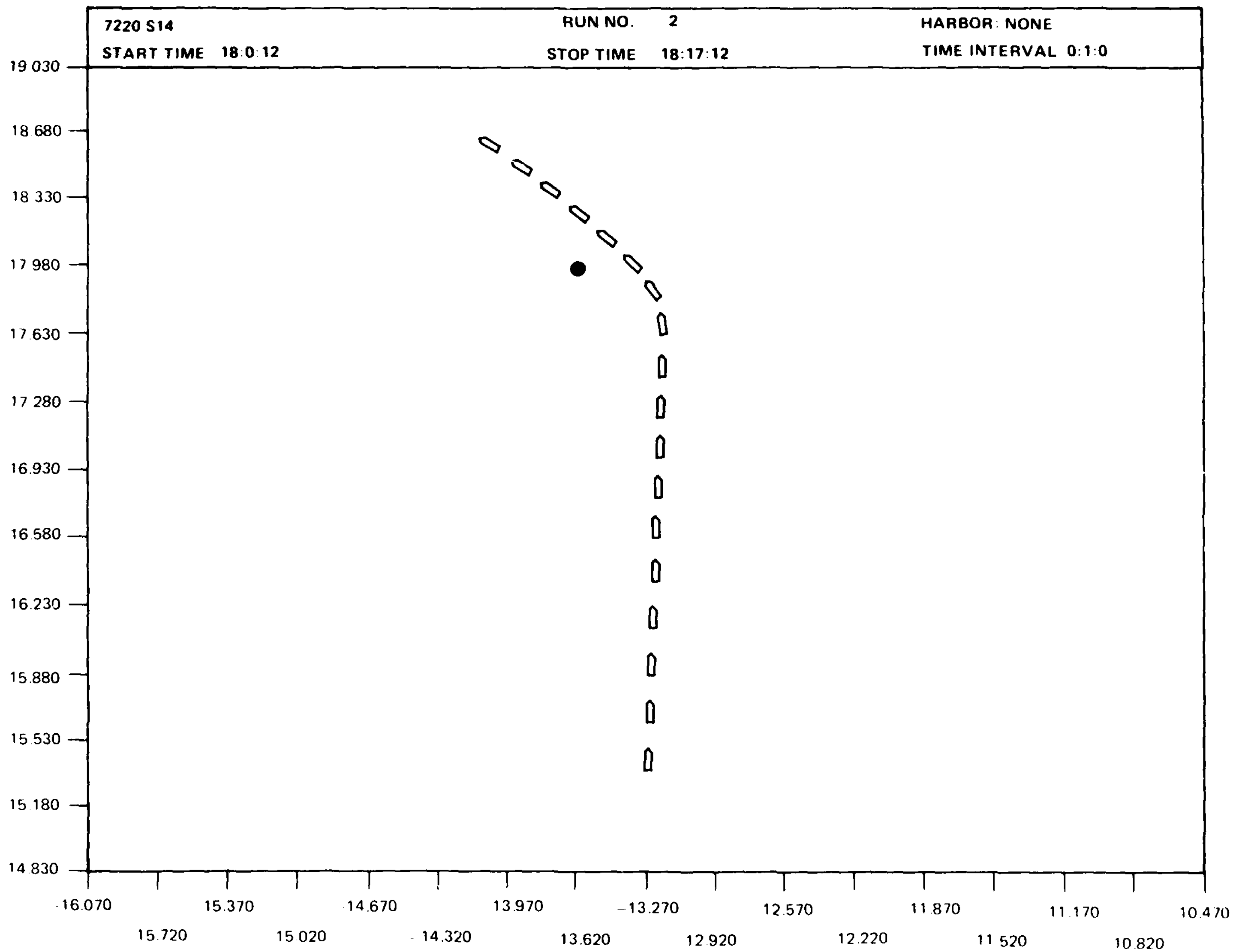

Figure A-24. Track Plots, Pilots, Leg A, Harbor Approach

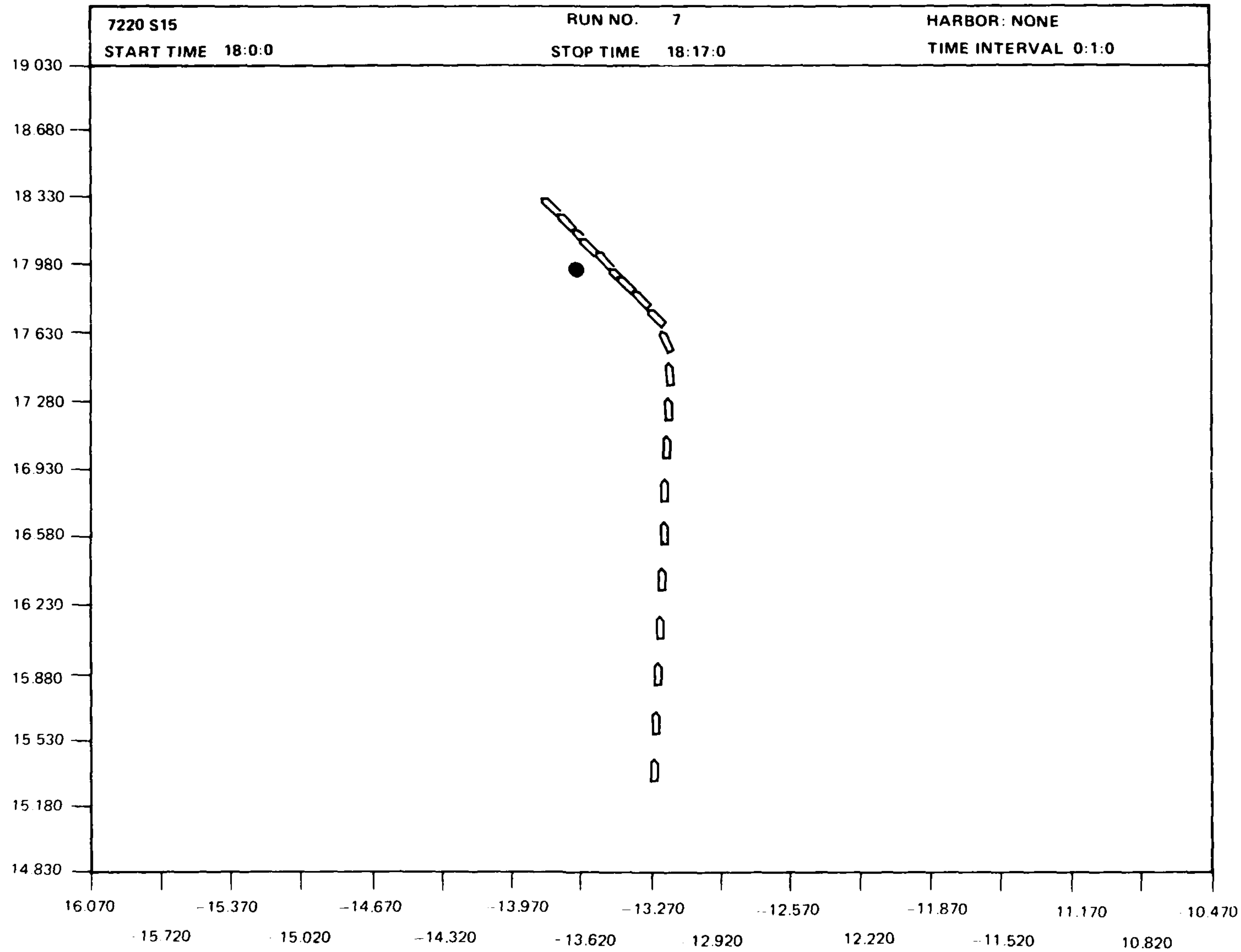

Figure A-25. Track Plots, Pilots, Leg A, Harbor Approach

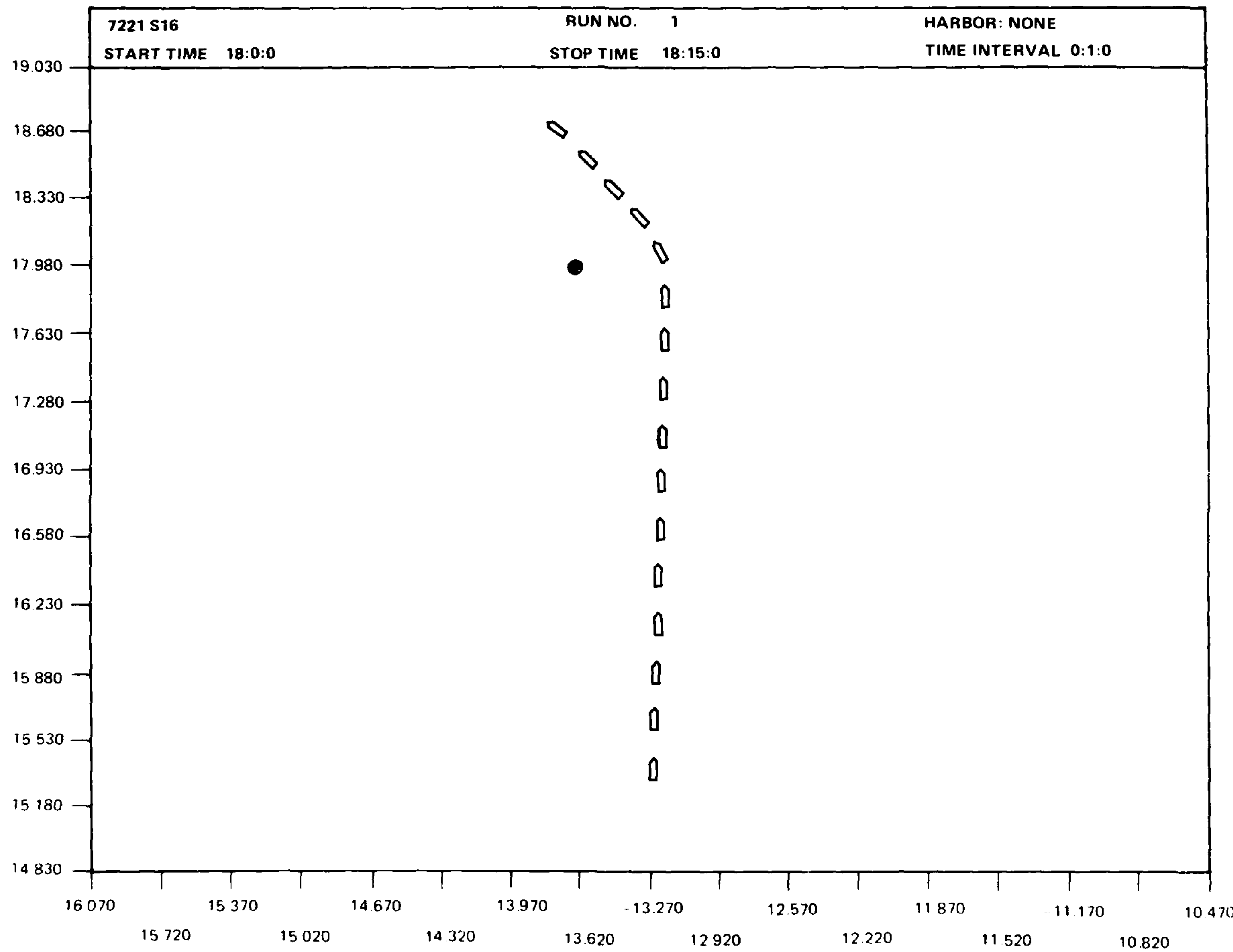

Figure A-26. Track Plots, Pilots, Leg A, Harbor Approach

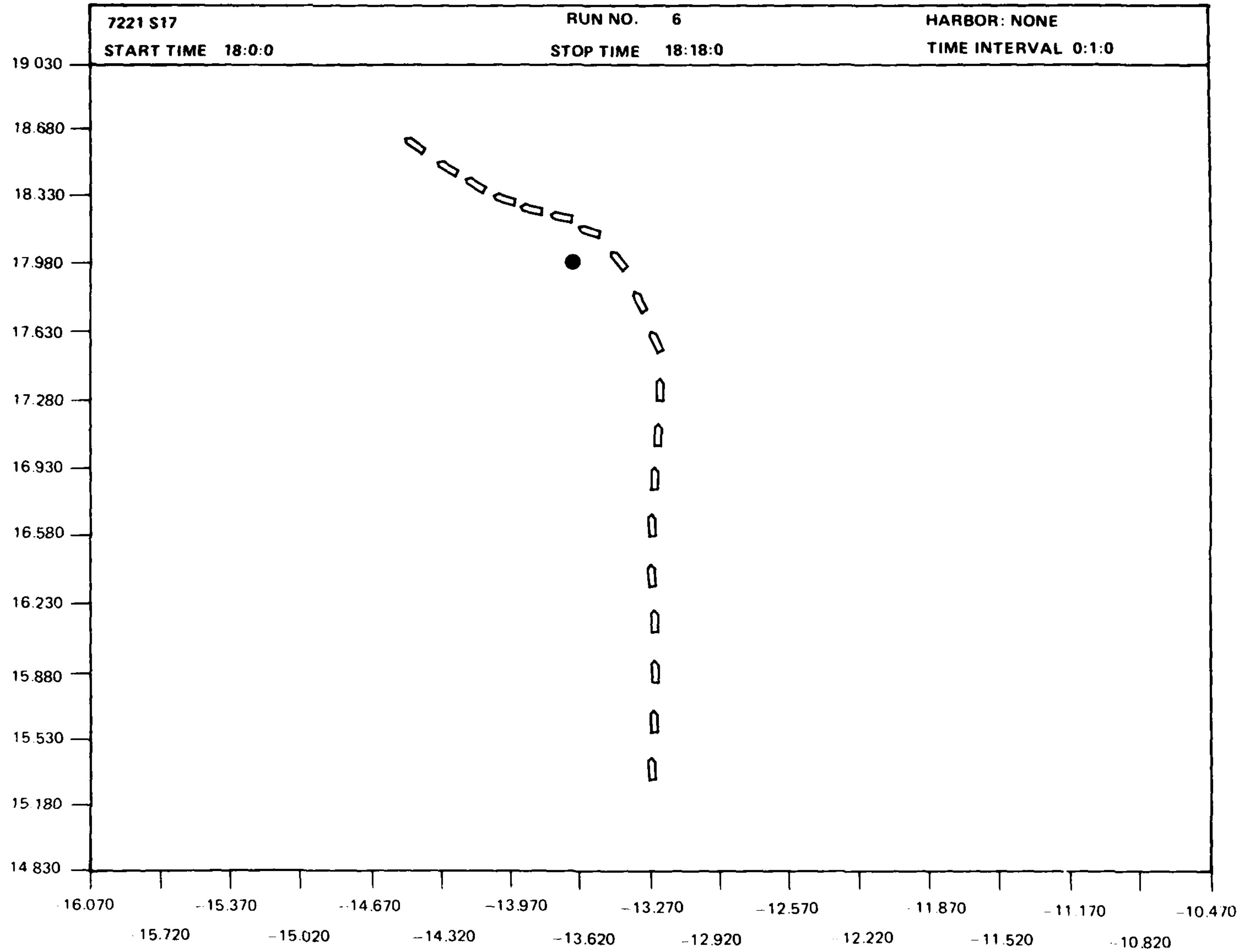

Figure A-27. Track Plots, Pilots, Leg A, Harbor Approach

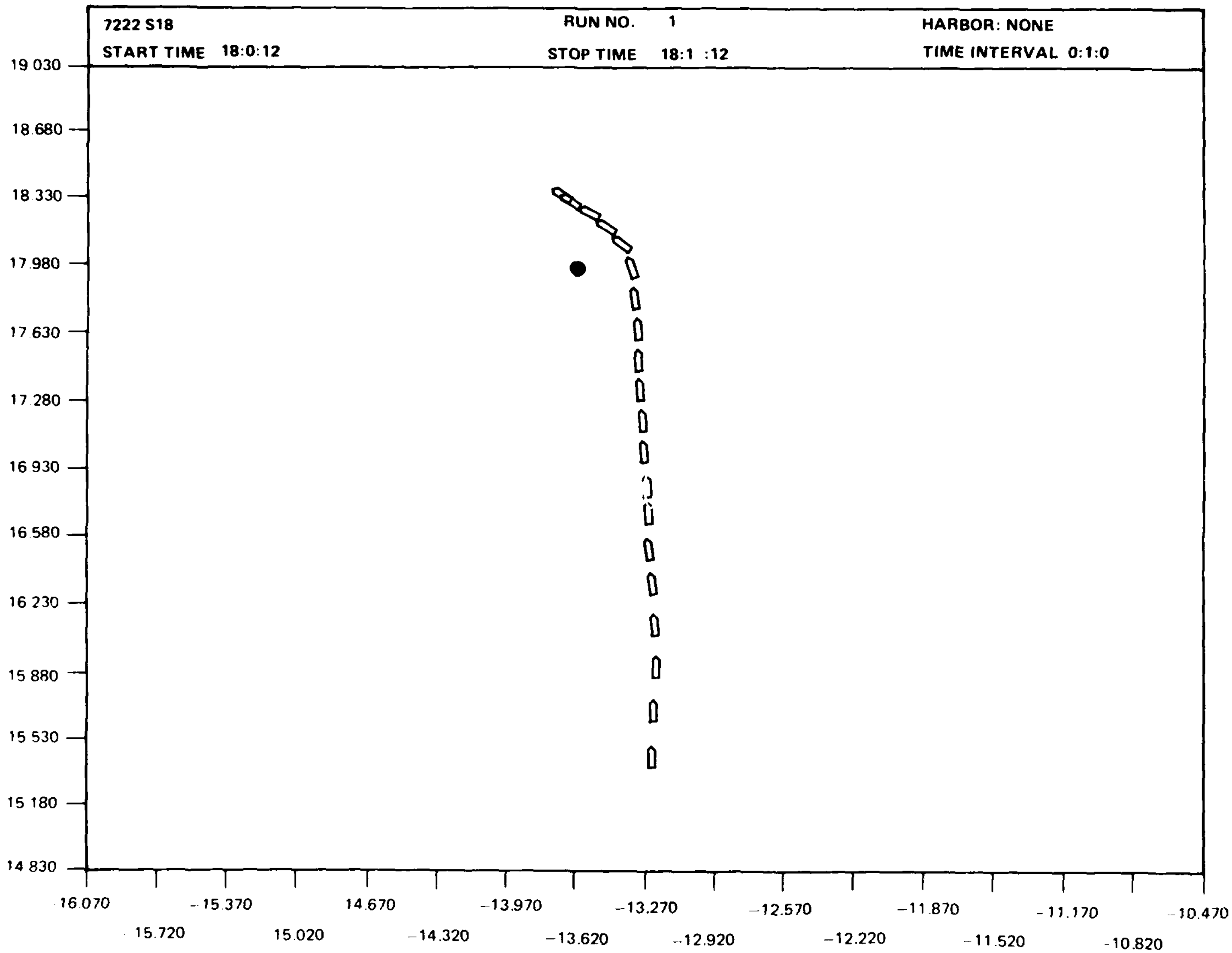

Figure A-28. Track Plots, Pilots, Leg A, Harbor Approach

TRAINING OBJECTIVE: Harbor Approach

PERFORMANCE MEASURE: Mean Deviation (in feet) Off Centerline

	Masters	**Pilots**
X	1028.55	757.43
SD	548.65	315.64
90% Confidence Interval	1288.55 to 769.45	906.32 to 607.68

Cutoff Score: > 906.32. Subjects with scores > 906.32 are considered not to have achieved criterion.

	Achieved Criterion	**Not Achieved Criterion**
Pilots	11	3
Masters	5	9

$\chi^2 = 5.25$, $p < 0.025$

χ^2 - (with Yates Correction) = 3.65, $p < 0.05$

Figure A-29. Summary of Data and Contingency Table, Mean Deviation (in feet) Off Centerline, Leg A, Harbor Approach

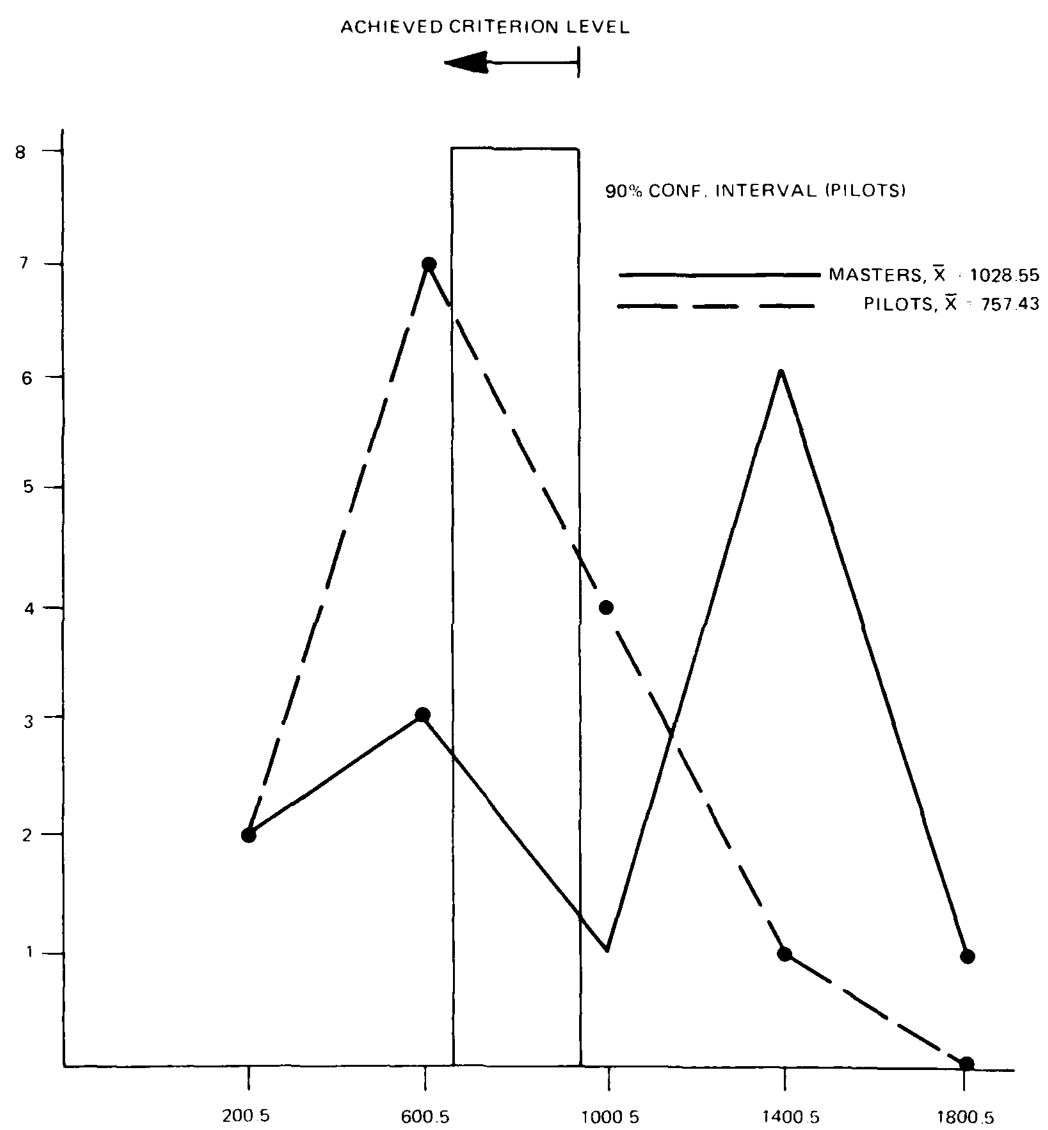

Figure A-30. Frequency Distribution and Confidence Interval, Mean Deviation (in feet) Off Centerline, Leg A, Harbor Approach

TRAINING OBJECTIVE: Harbor Approach

PERFORMANCE MEASURE: Maximum Deviation (in feet) Off Centerline

	Masters	Pilots
X	2324	1915
SD	1232	791
90% Confidence Interval	2906.81 to 1741.19	2289.18 to 1540.82

Cutoff Score: > 2289.18. Subjects with scores > 2289.18 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	5	9

$\chi^2 = 5.25, p < 0.025$

χ^2 (with Yates Correction) $= 3.65, p < 0.05$

Figure A-31. Summary of Data and Contingency Table, Maximum Deviation (in feet) Off Centerline, Leg A, Harbor Approach

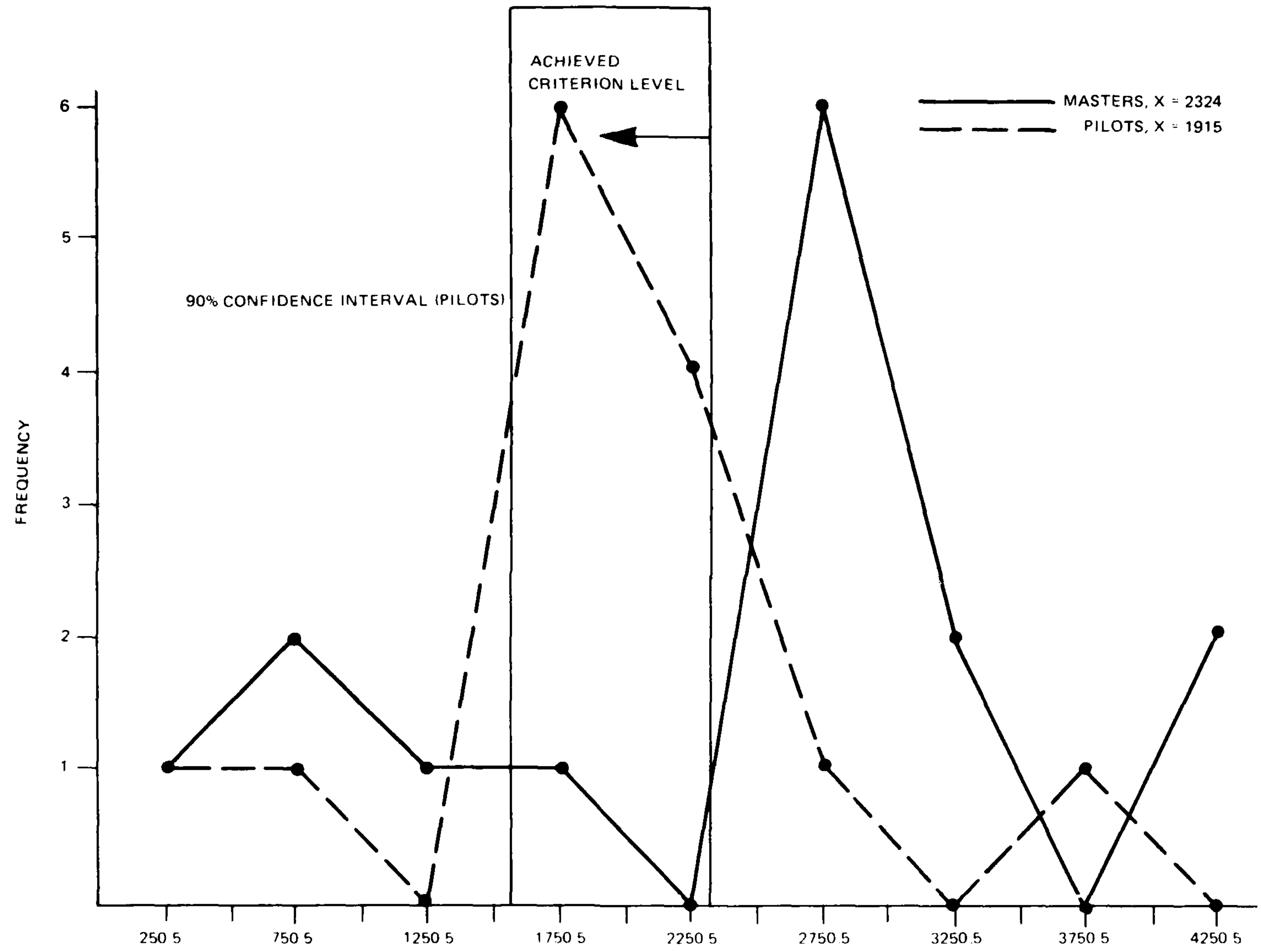

Figure A-32. Frequency Distribution and Confidence Interval, Maximum Deviation (in feet) Off Centerline, Leg A, Harbor Approach

TRAINING OBJECTIVE: Harbor Approach

PERFORMANCE MEASURE: Mean Deviation (in feet) Off Average Trackline

	Masters	Pilots*
$\bar{X}$	520.12	300.40
SD	231.28	164.22
90% Confidence Interval	629.52 to 410.72	384.31 to 216.48

Cutoff Score: > 384.31. Subjects with scores > 384.31 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	10	2
Masters	5	9

$\chi^2 = 6.00$, $p < 0.01$

χ^2 = (with Yates Correction) = 4.21, $p < 0.05$

*N = 12, see text page 26.

Figure A-33. Summary of Data and Contingency Table, Mean Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach

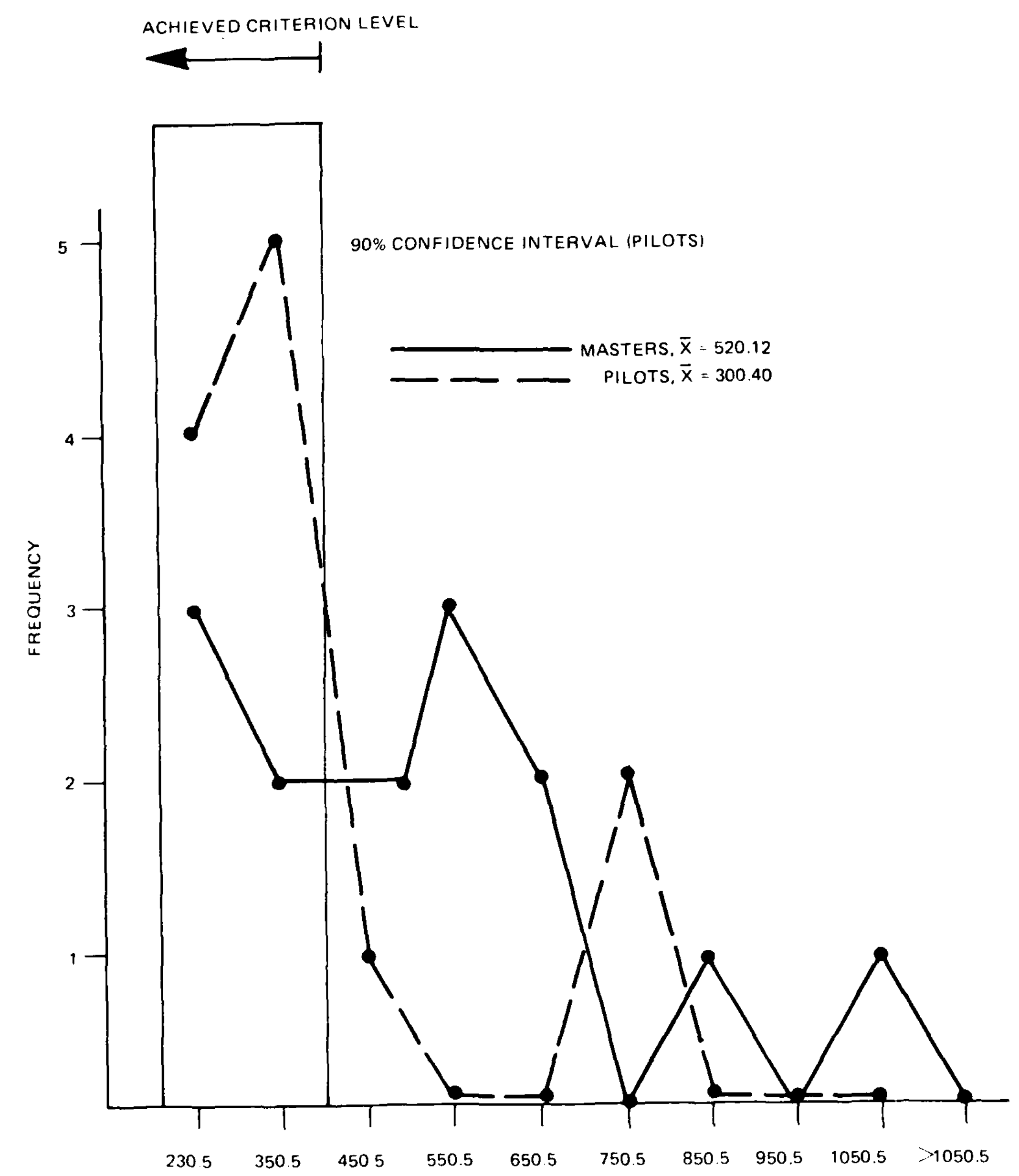

Figure A-34. Frequency Distribution and Confidence Interval, Mean Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach

TRAINING OBJECTIVE: Harbor Approach

PERFORMANCE MEASURE: Maximum Deviation (in feet) Off Average Trackline

	Masters	Pilots
$\bar{X}$	1920.30	1079.30
SD	690.24	735.44
90% Confidence Interval	2246.61 to 1593.79	1455.07 to 703.52

Cutoff Score: > 1455.07. Subjects with scores > 1455.07 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	8	4
Masters	3	11

$\chi^2 = 5.42, p < 0.05$

χ^2 = (with Yates Correction) = $3.72, p < 0.10$

Figure A-35. Summary of Data and Contingency Table, Maximum Deviation (in feet) Off Average Trackline, Leg A, Harbor Approach

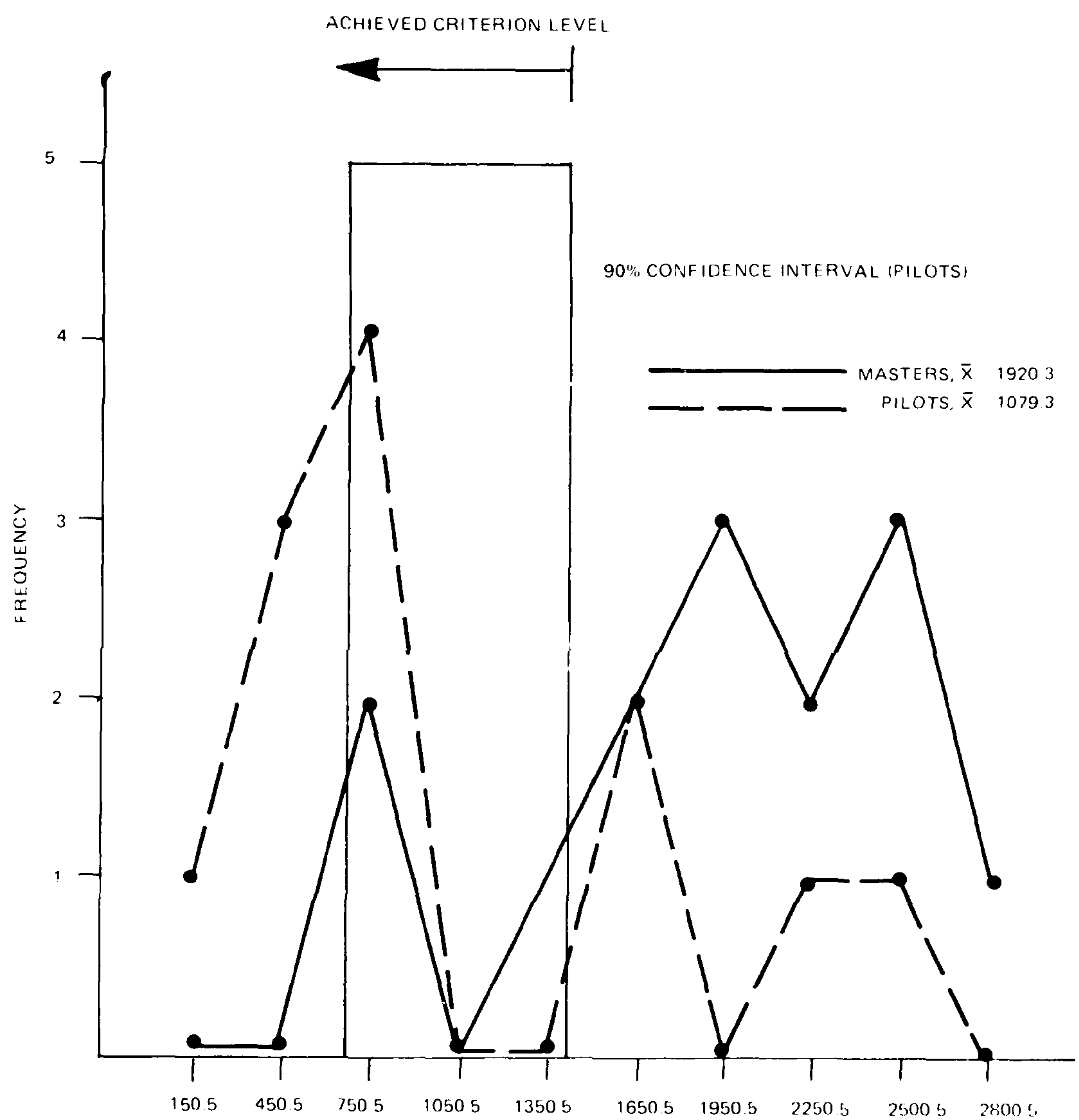

Figure A-36. Frequency Distribution and Confidence Interval, Maximum Deviation (in feet) Off Averge Trackline, Leg A, Harbor Approach

APPENDIX B

PERFORMANCE MEASURES APPENDICES

LEG 1 – RUDDER FAILURE

TRAINING OBJECTIVE: SHIPHANDLING IN RESPONSE TO RUDDER FAILURE IN CONFINED WATERS

The track plots (Figures B-1 through B-28) which follow depict the position of ownship with respect to three anchored ships. In this scenario, ownship experienced a rudder failure jamming the rudder at 15 degrees left. By properly using thruster and engine power the master could avoid colliding with any of the three anchored ships or any of the piers depicted to the left of each track plot. A representation of ownship was plotted at one minute intervals. Thus, five representatives of ownship in the track plot indicate ownship's position over a four minute period. (A representation of ownship is always provided for starting position.) The x and y coordinate scales are references to position in the data base.

LIST OF ILLUSTRATIONS

Number	
B-1 to B-14	Track Plots, Master, Leg 1, Rudder Failure
B-15 to B-28	Track Plots, Pilots, Leg 1, Rudder Failure
B-29	Summary of Data and Contingency Table, CPA (in feet) to Ship 3 Including Collisions, Leg 1, Rudder Failure
B-30	Frequency Distribution and Confidence Interval, CPA (in feet) to Ship 3 Including Collisions, Leg 1, Rudder Failure
B-31	Summary of Data and Contingency Table, CPA (in feet) to Ship 3 Excluding Collisions, Leg 1, Rudder Failure
B-32	Frequency Distribution, CPA (in feet) to Ship 3 Excluding Collisions, Leg 1, Rudder Failure
B-33	Summary of Data and Contingency Table, CPA (in feet) to Ship 4, Leg 1, Rudder Failure
B-34	Frequency Distribution and Confidence Interval, CPA (in feet) to Ship 4, Leg 1, Rudder Failure
B-35	Summary of Data and Contingency Table, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Including Collisions, Leg 1, Rudder Failure
B-36	Frequency Distribution and Confidence Interval, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Including Collisions, Leg 1, Rudder Failure

LIST OF ILLUSTRATIONS (Continued)

Number

B-37 Summary of Data and Contingency Table, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Excluding Collisions, Leg 1, Rudder Failure

B-38 Frequency Distribution, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Excluding Collisions, Leg 1, Rudder Failure

B-39 Summary of Data and Contingency Table, Time (in seconds) to Reduce Rate of Turn to More Than 0.1°/Second Including Collisions, Leg 1, Rudder Failure

B-40 Frequency Distribution, Time (in seconds) to Reduce Rate of Turn to More Than 0.1°/Second Including Collisions, Leg 1, Rudder Failure

B-41 Summary of Data and Contingency Table, Time (in seconds) to Reduce Rate of Turn to More Than 0.1°/Second Excluding Collisions, Leg 1, Rudder Failure

B-42 Frequency Distribution, Time (in seconds) to Reduce Rate of Turn to More Than 0.1°/Second Excluding Collisions, Leg 1, Rudder Failure

B-43 Percent of Rudder, Engine RPM, and Thruster Remaining, Leg 1, Rudder Failure

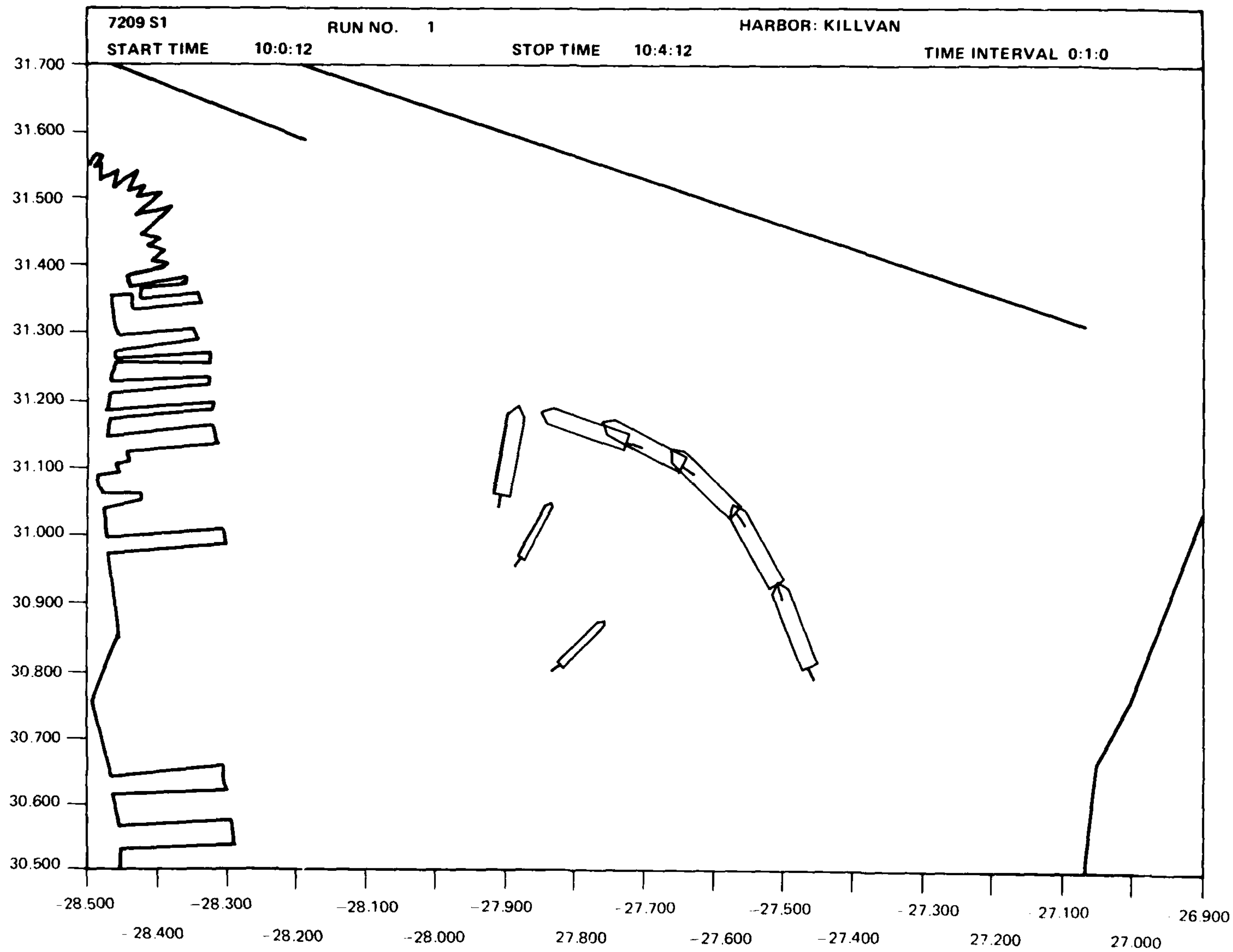

Figure B-1. Track Plots, Masters, Leg 1, Rudder Failure

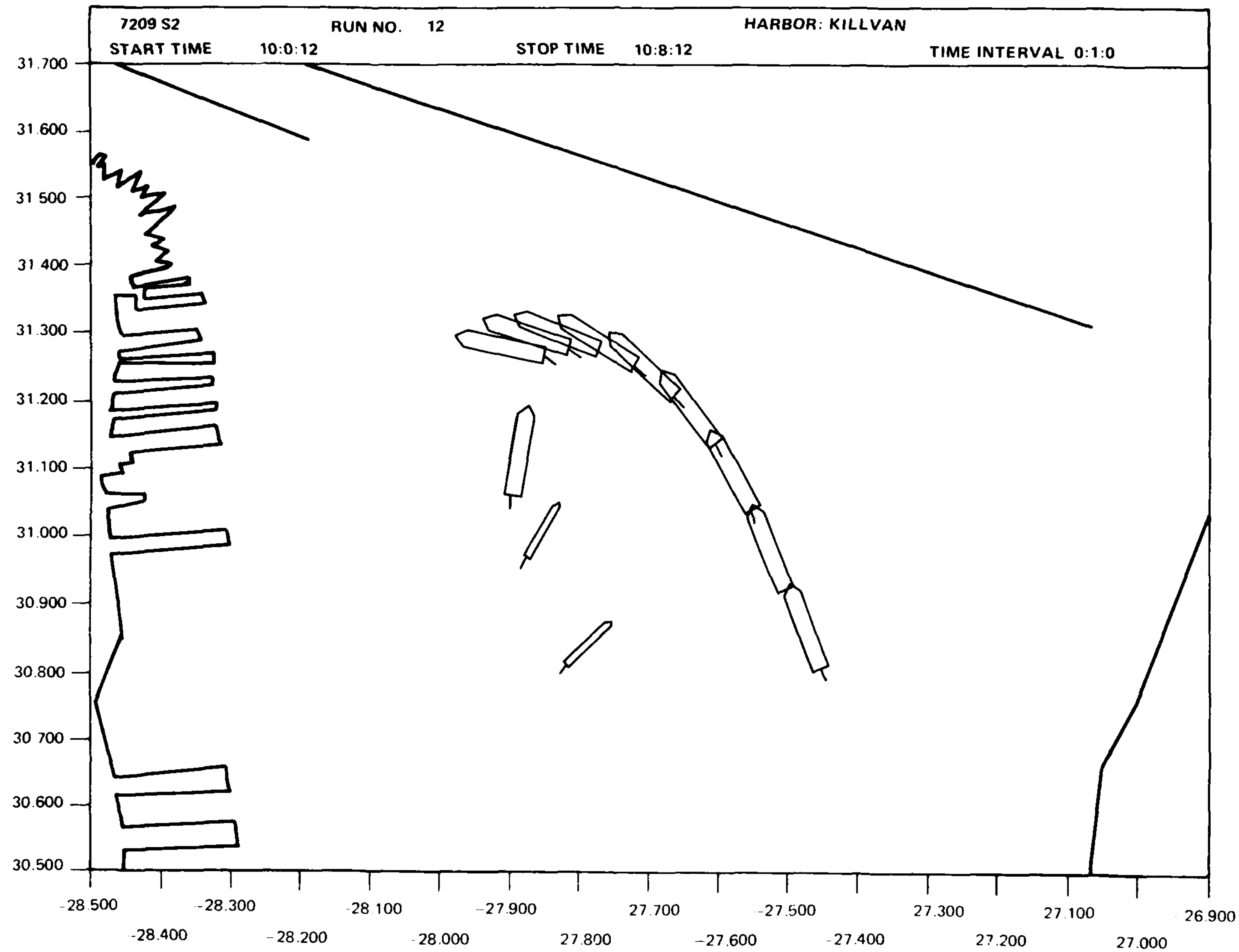

Figure B-2. Track Plots, Masters, Leg 1, Rudder Failure

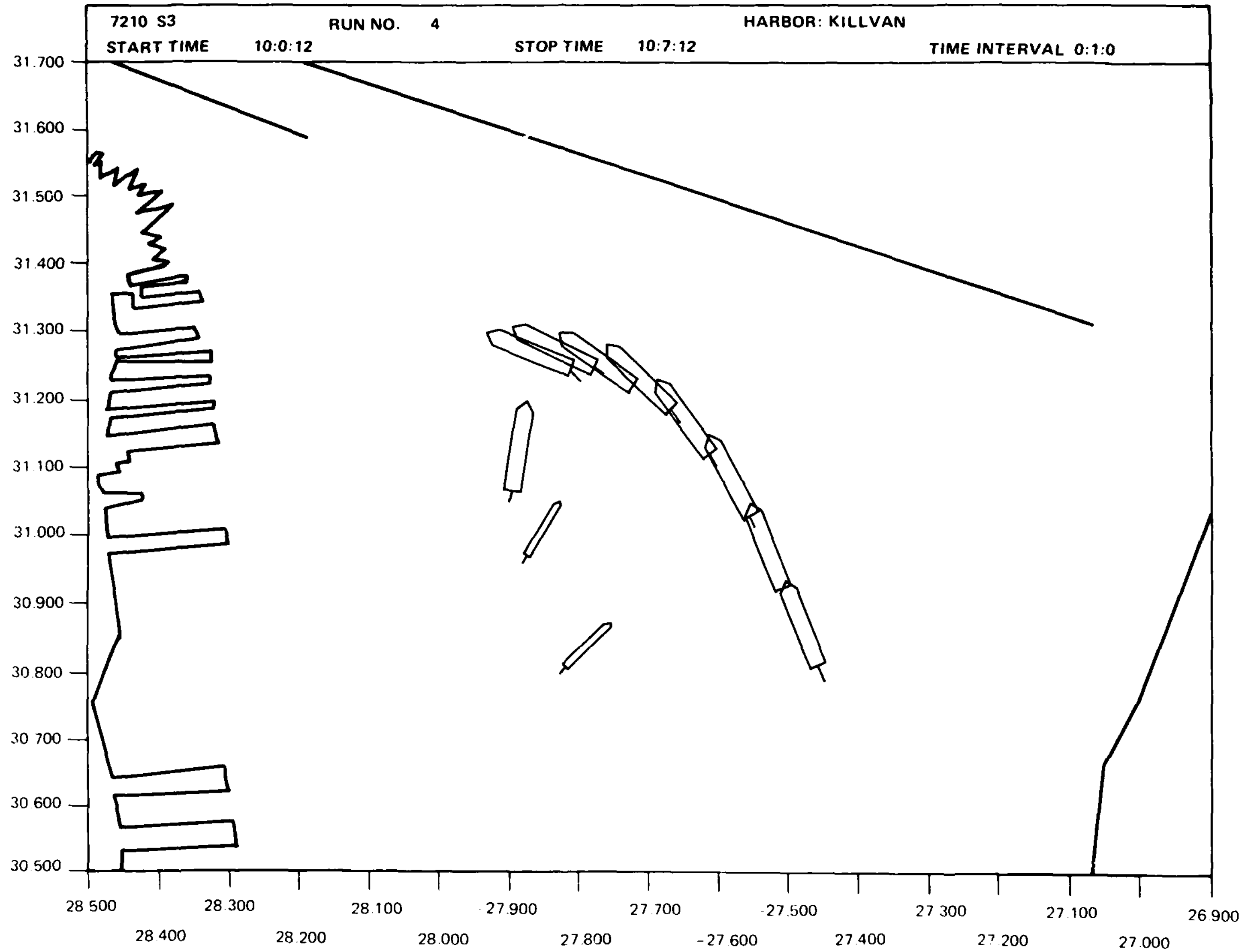

Figure B-3. Track Plots, Masters, Leg 1, Rudder Failure

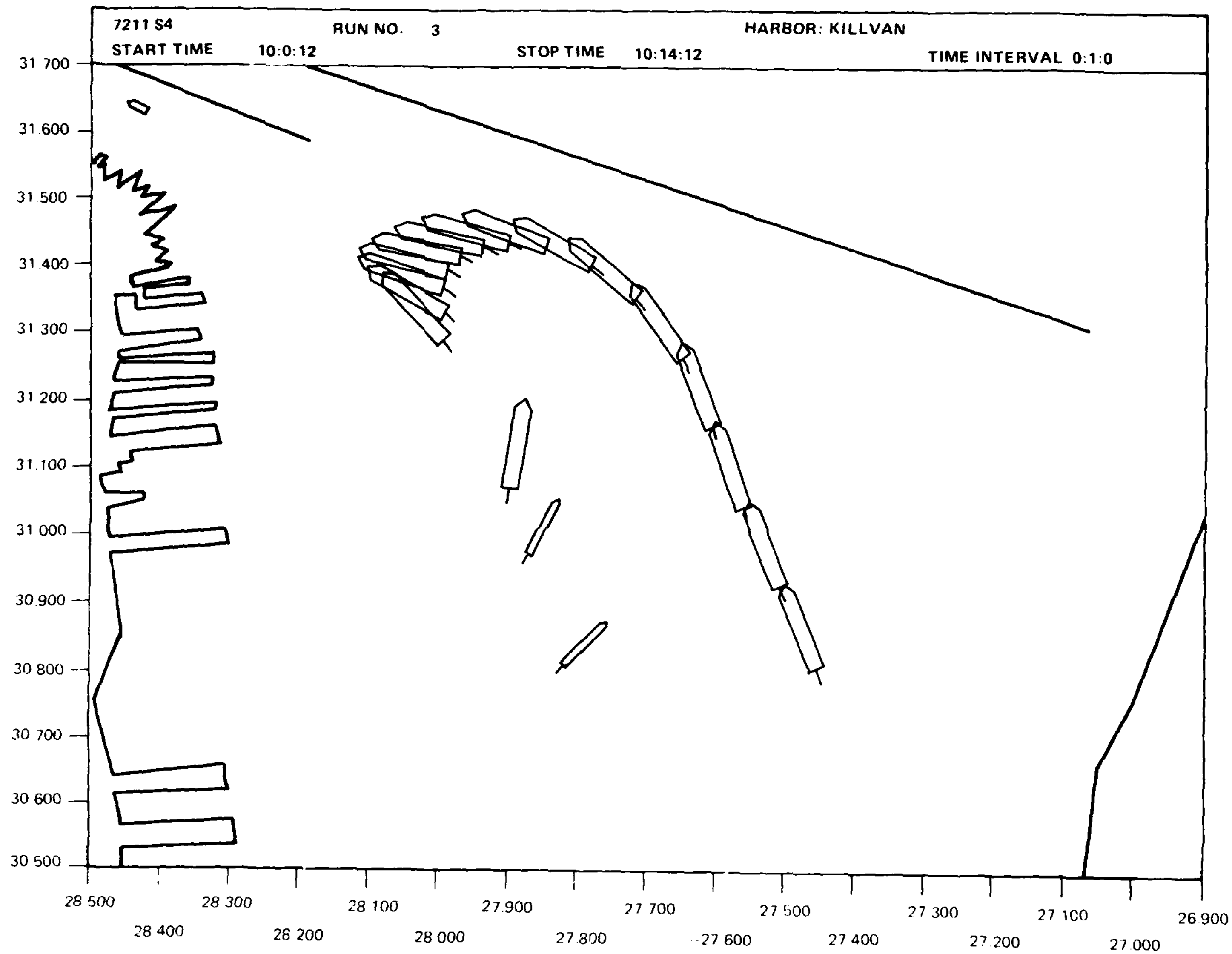

Figure B-4. Track Plots, Masters, Leg 1, Rudder Failure

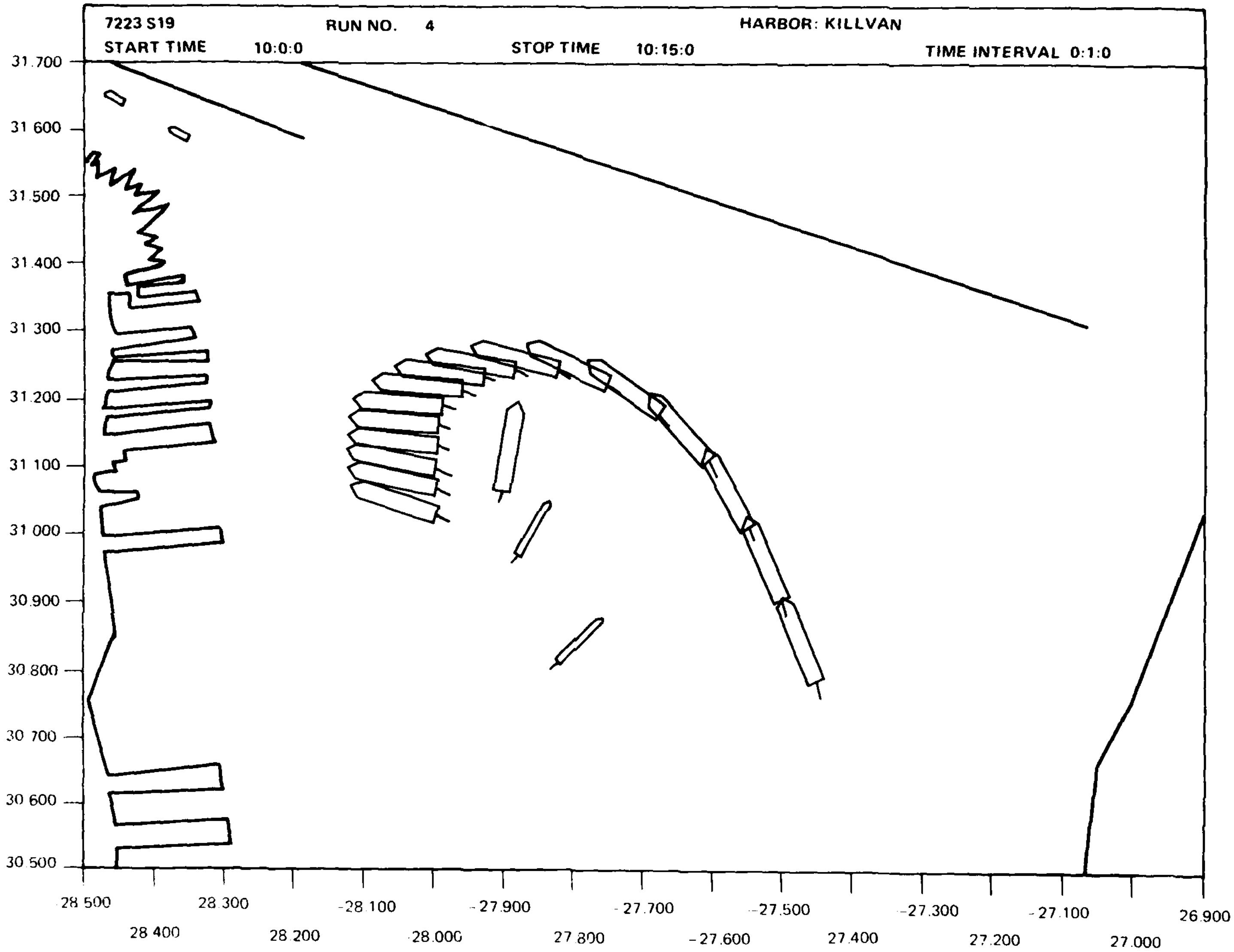

Figure B-5. Track Plots, Masters, Leg 1, Rudder Failure

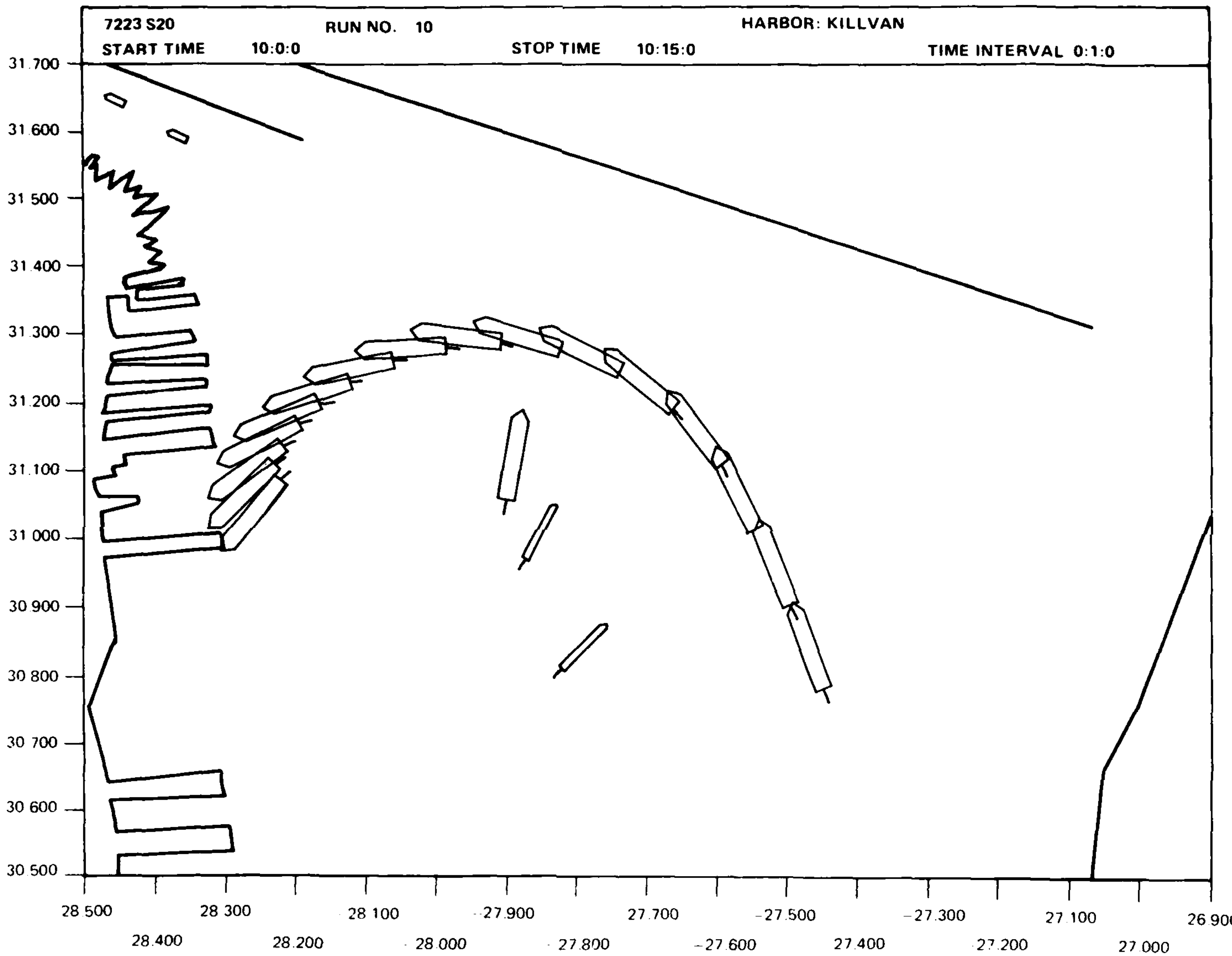

Figure B-6. Track Plots, Masters, Leg 1, Rudder Failure

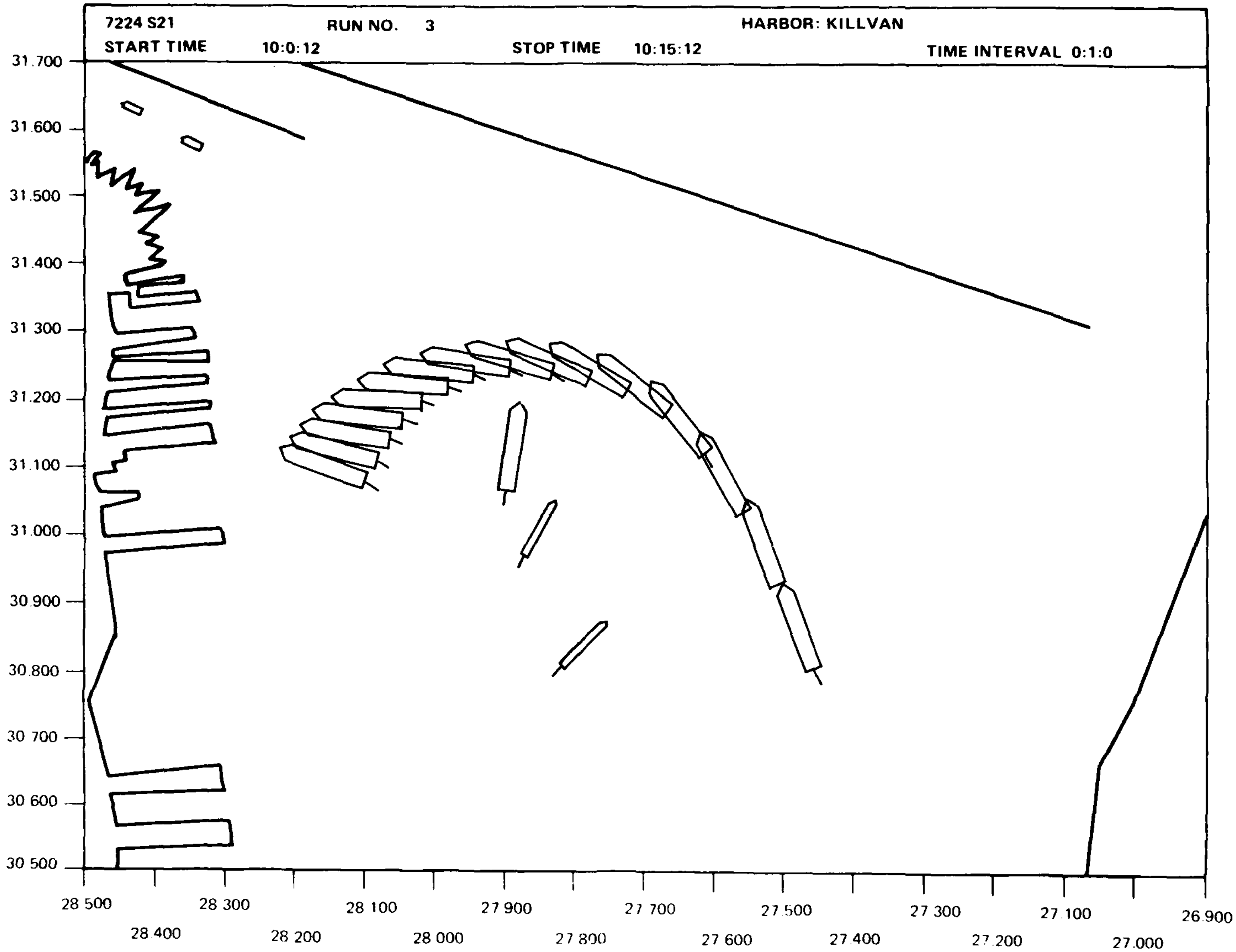

Figure B-7. Track Plots, Masters, Leg 1, Rudder Failure

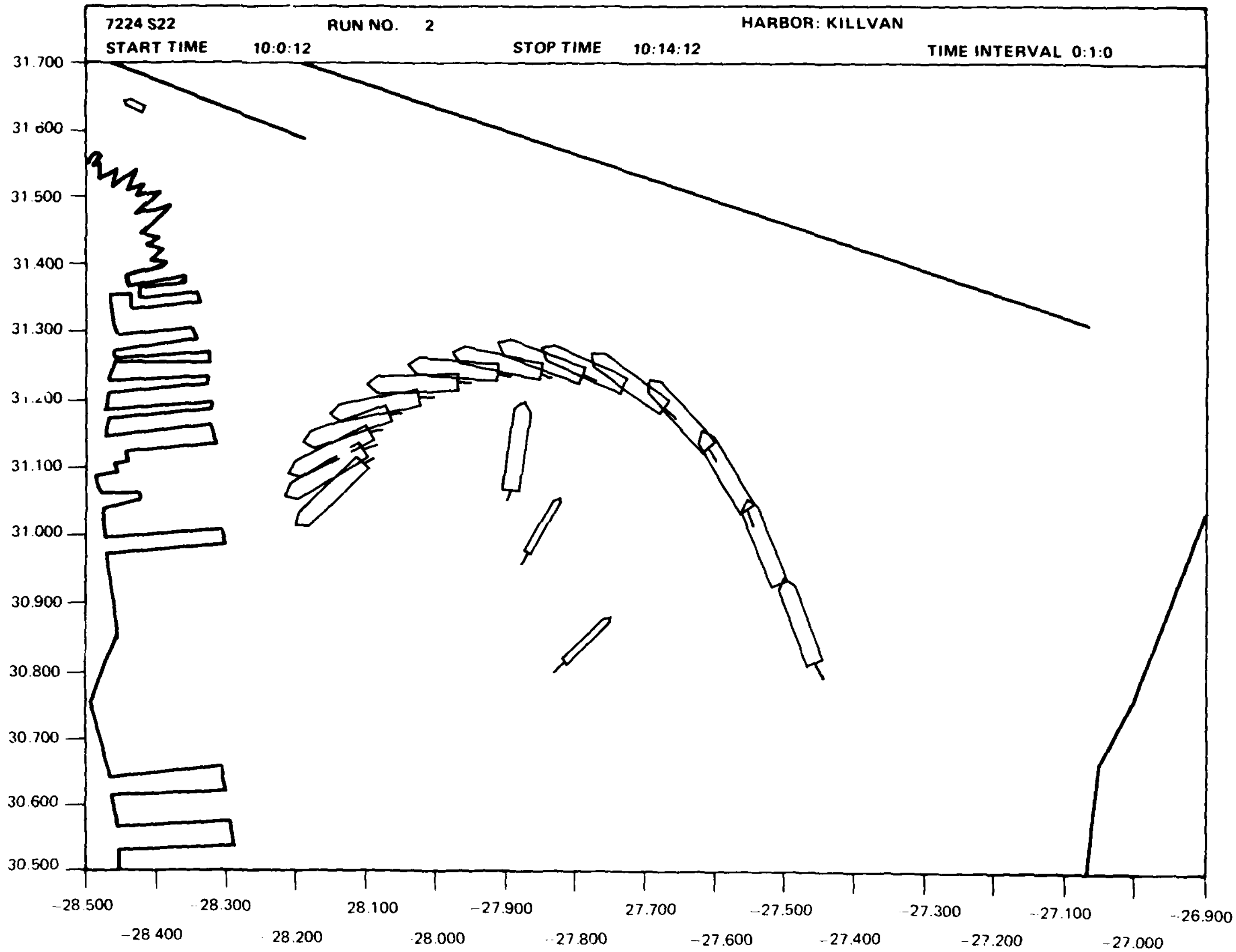

Figure B-8. Track Plots, Masters, Leg 1, Rudder Failure

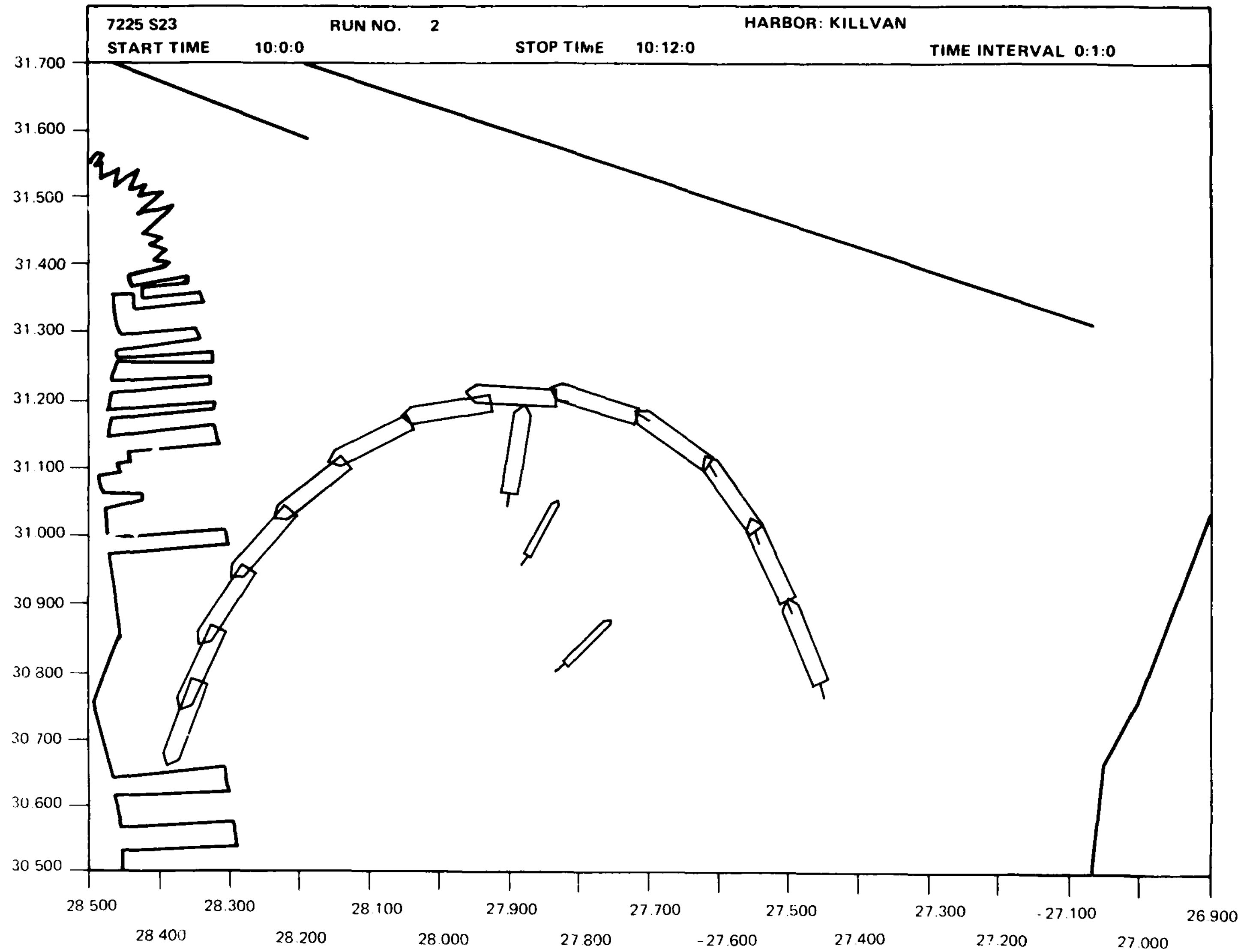

Figure B-9. Track Plots, Masters, Leg 1, Rudder Failure

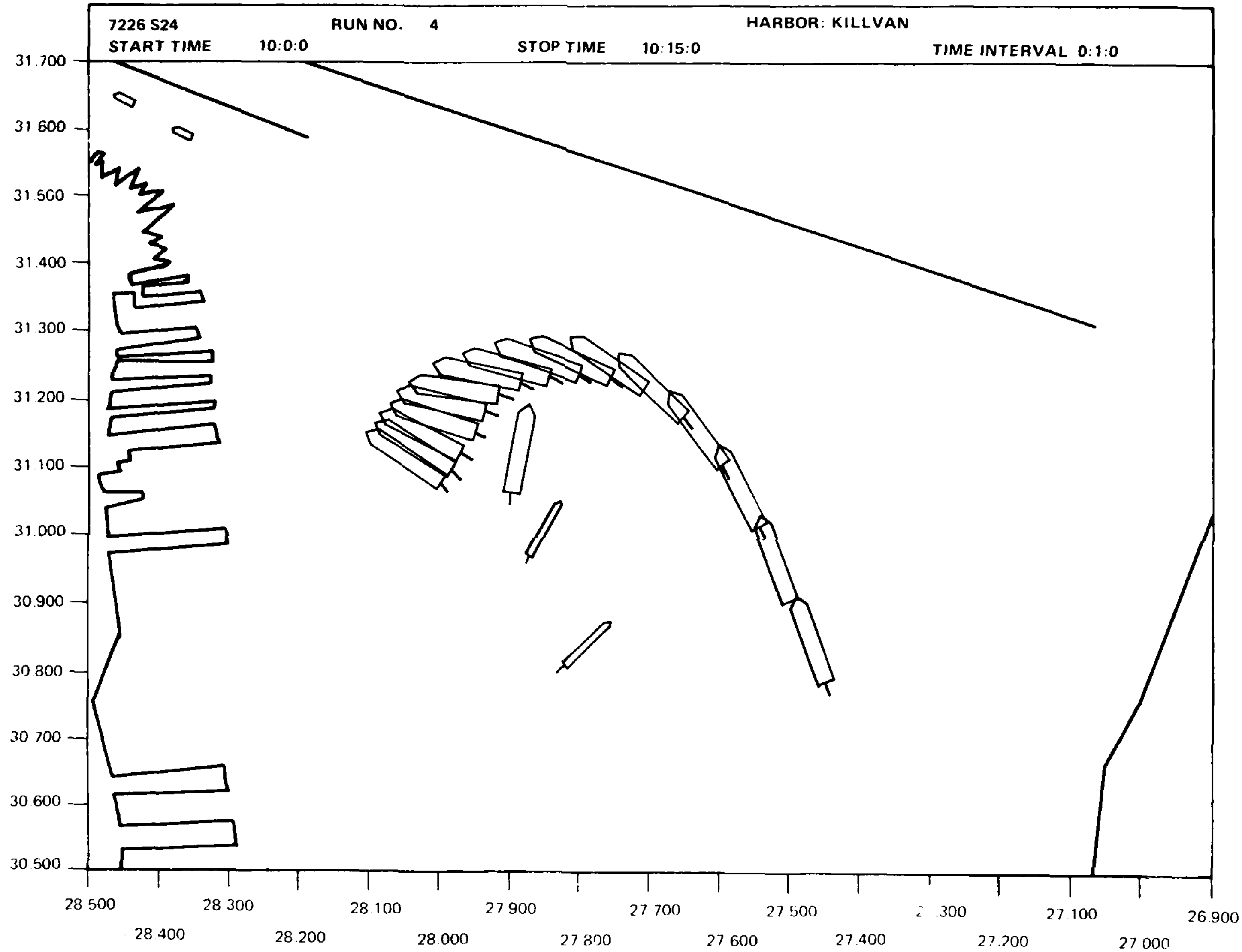

Figure B-10. Track Plots, Masters, Leg 1, Rudder Failure

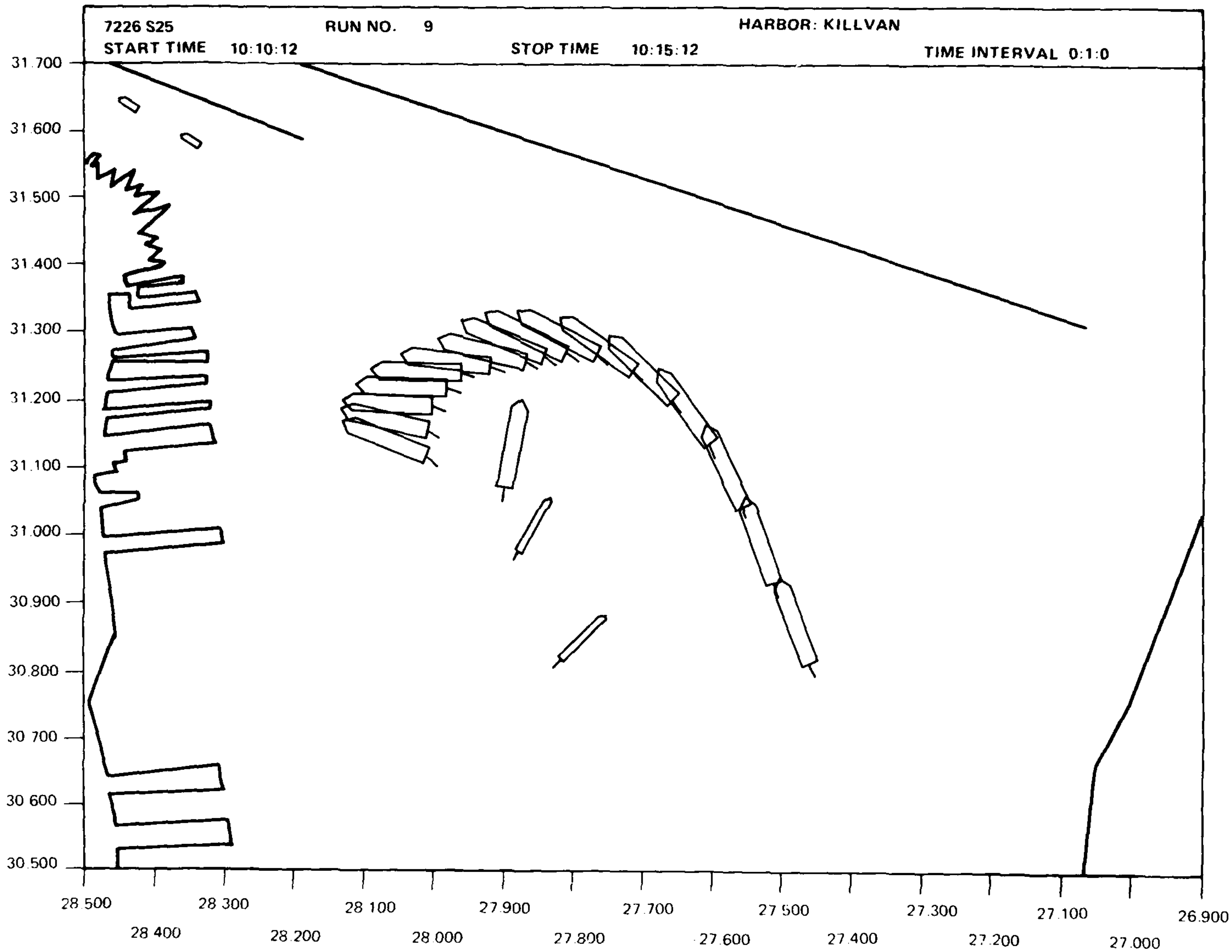

Figure B-11. Track Plots, Masters, Leg 1, Rudder Failure

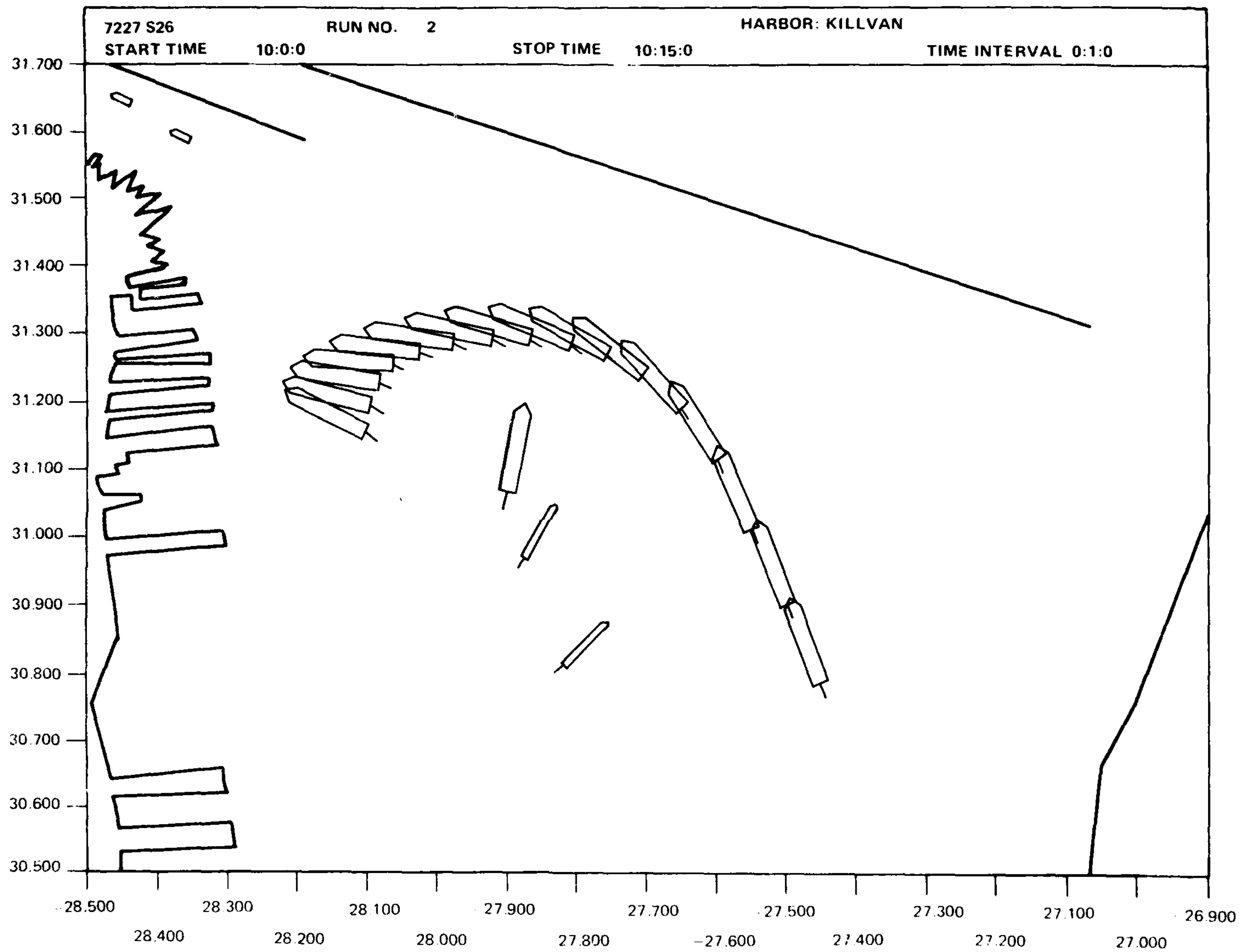

Figure B-12. Track Plots, Masters, Leg 1, Rudder Failure

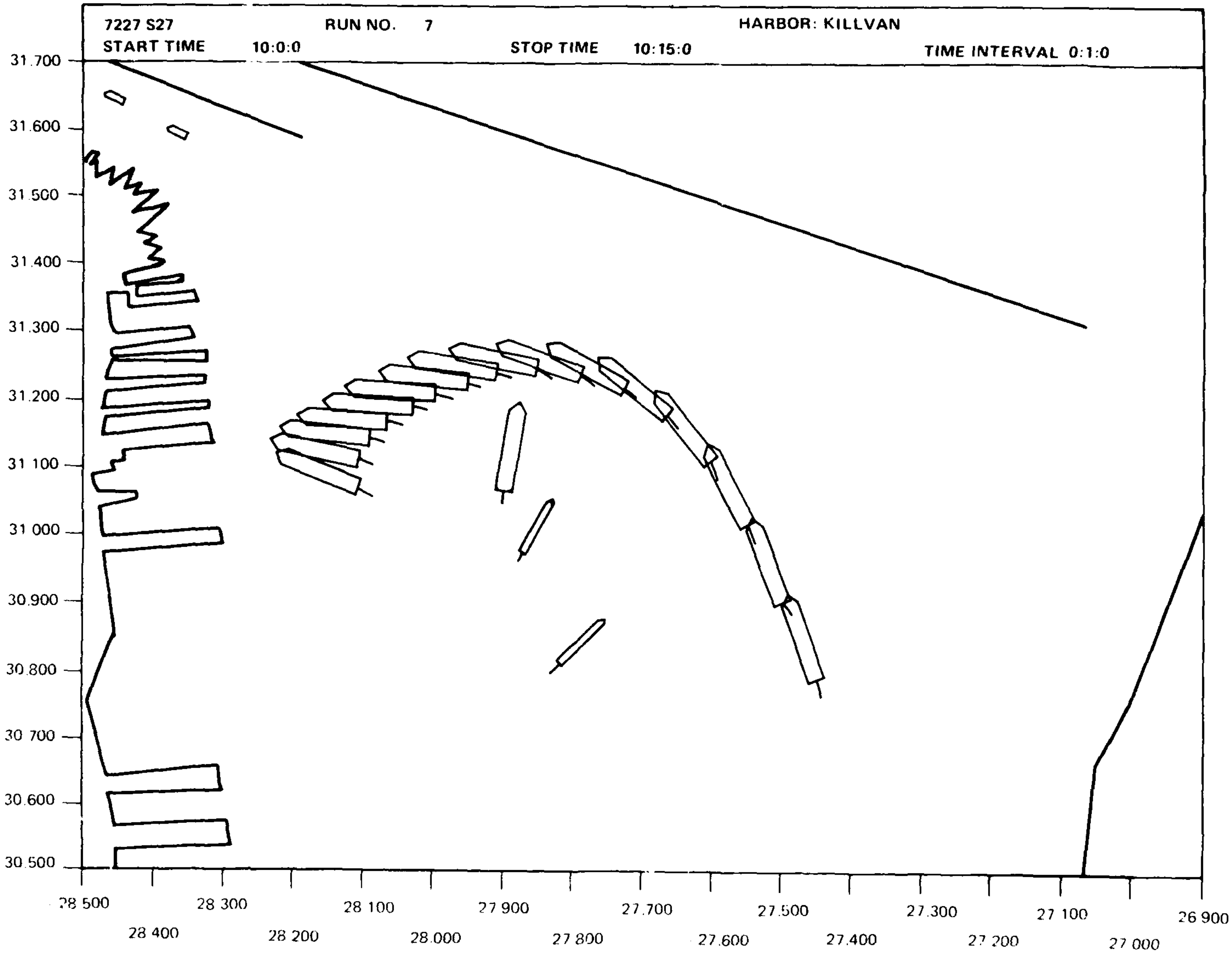

Figure B-13. Track Plots, Masters, Leg 1, Rudder Failure

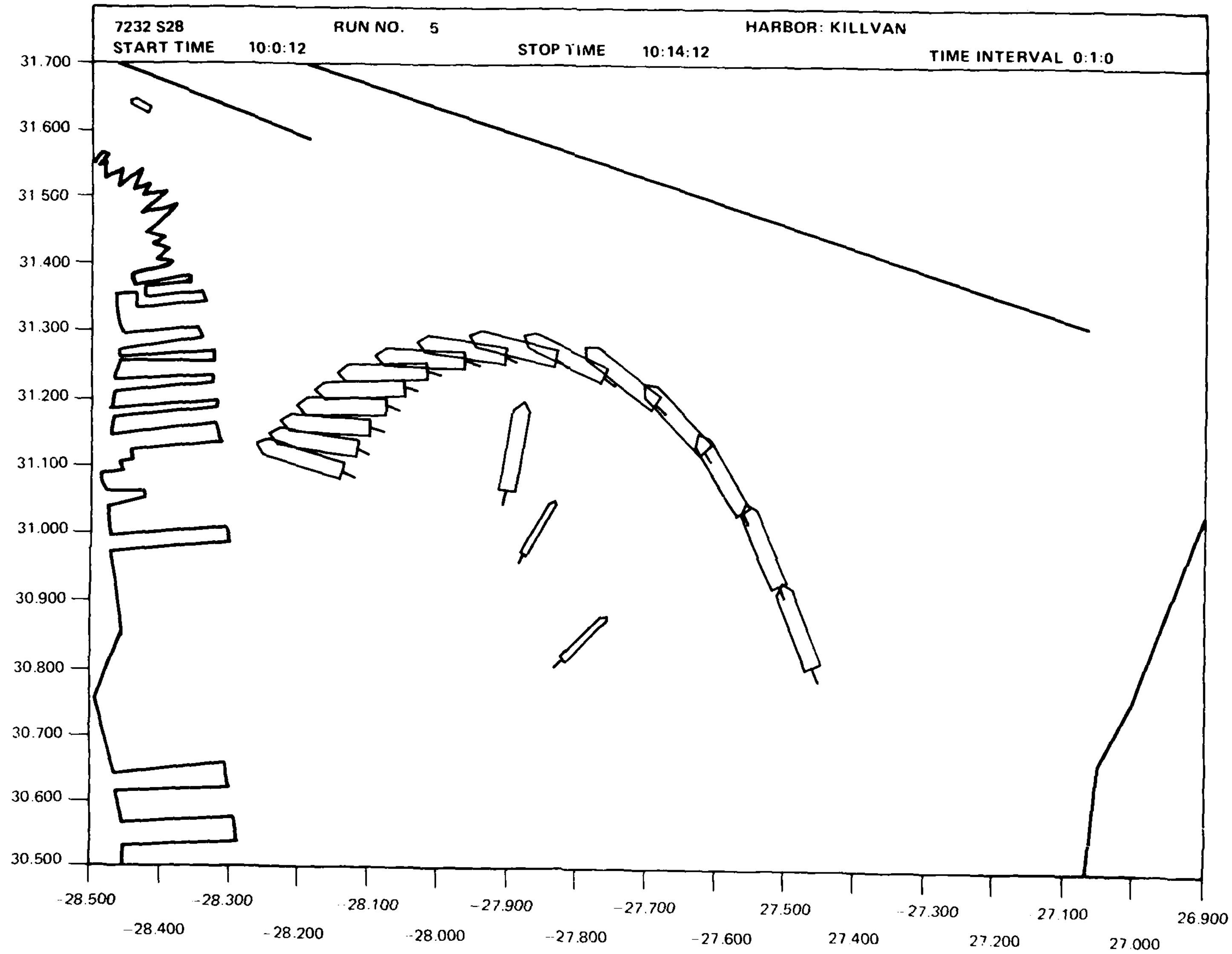

Figure B-14. Track Plots, Masters, Leg 1, Rudder Failure

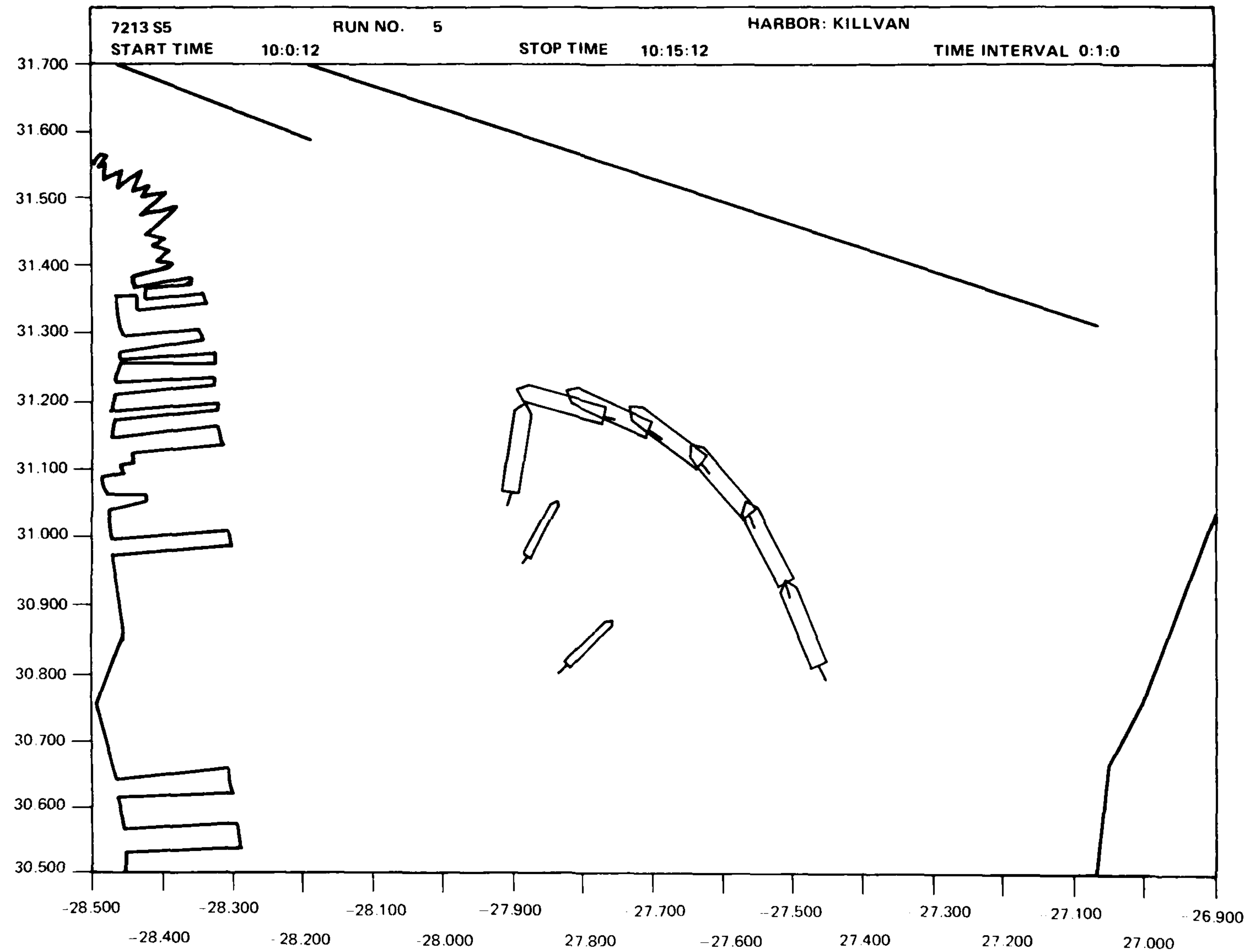

Figure B-15. Track Plots, Pilots, Leg 1, Rudder Failure

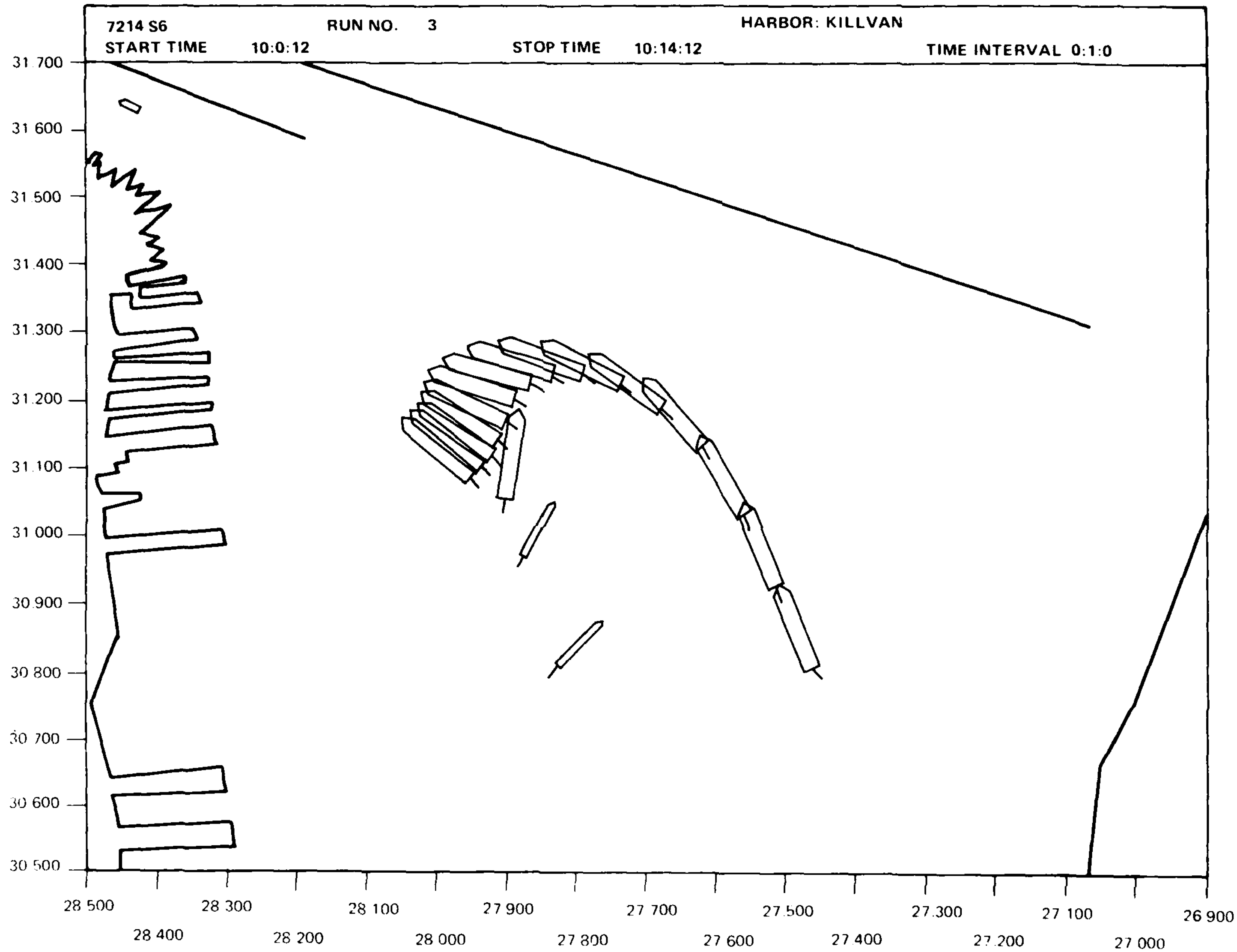

Figure B-16. Track Plots, Pilots, Leg 1, Rudder Failure

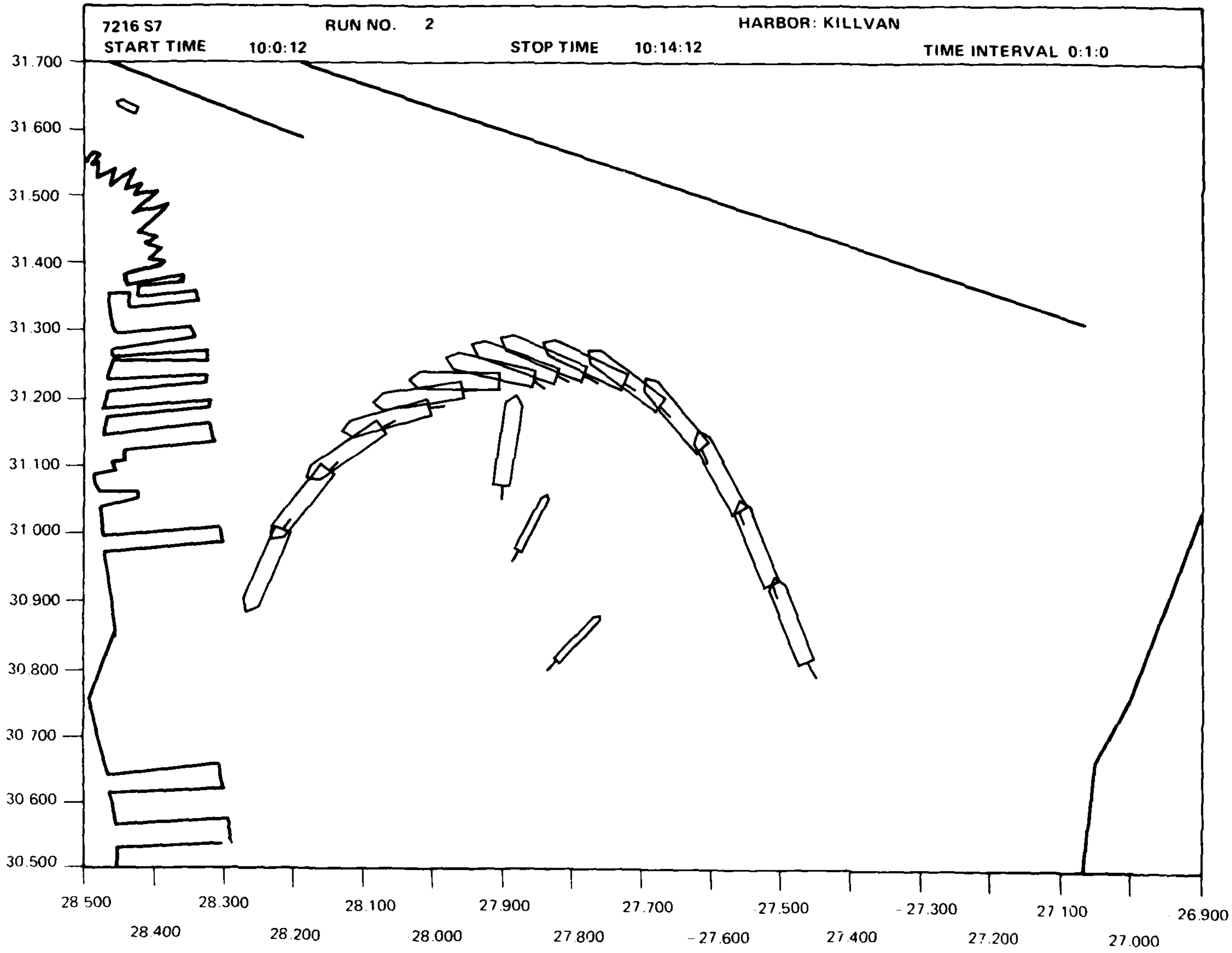

Figure B-17. Track Plots, Pilots, Leg 1, Rudder Failure

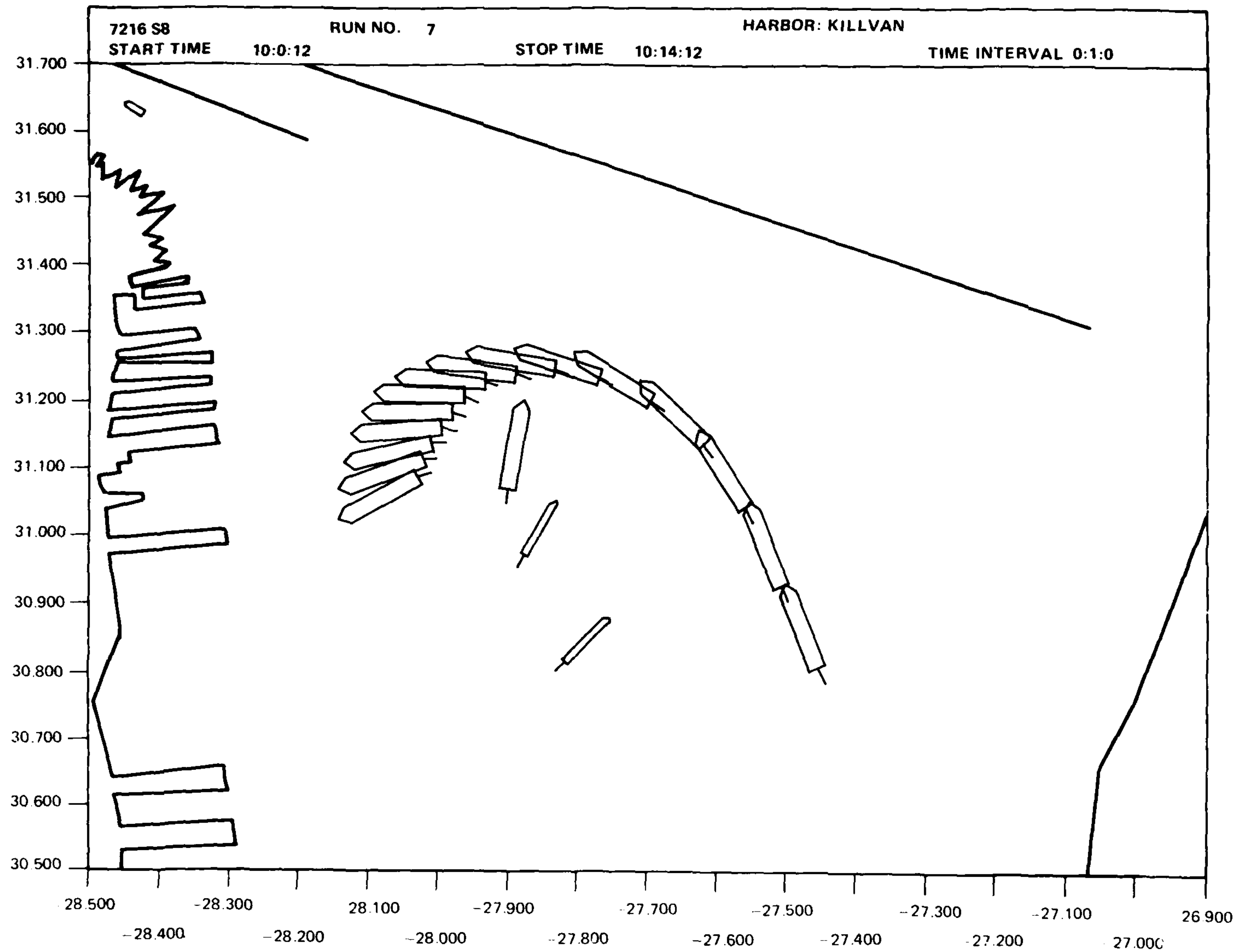

Figure B-18. Track Plots, Pilots, Leg 1, Rudder Failure

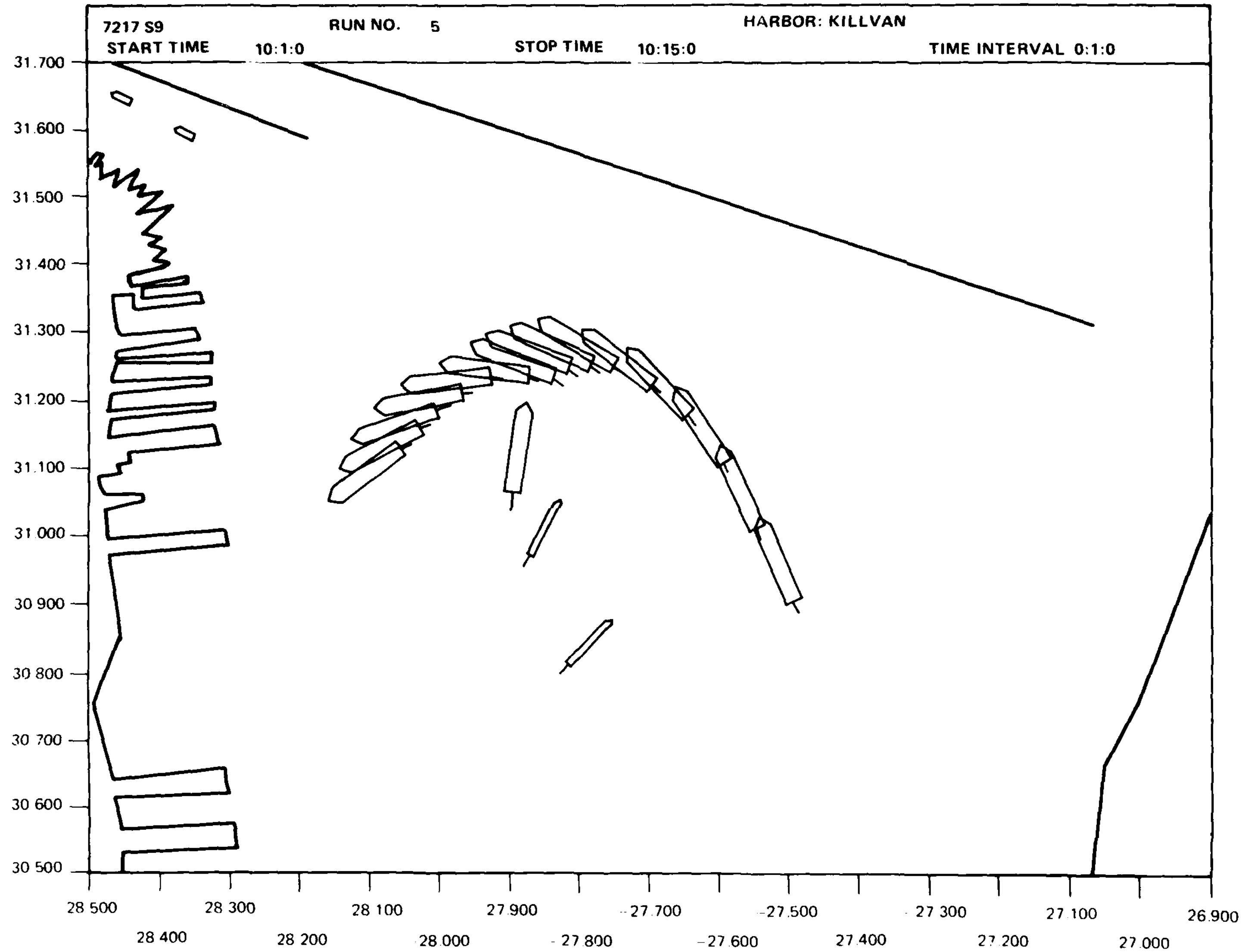

Figure B-19. Track Plots, Pilots, Leg 1, Rudder Failure

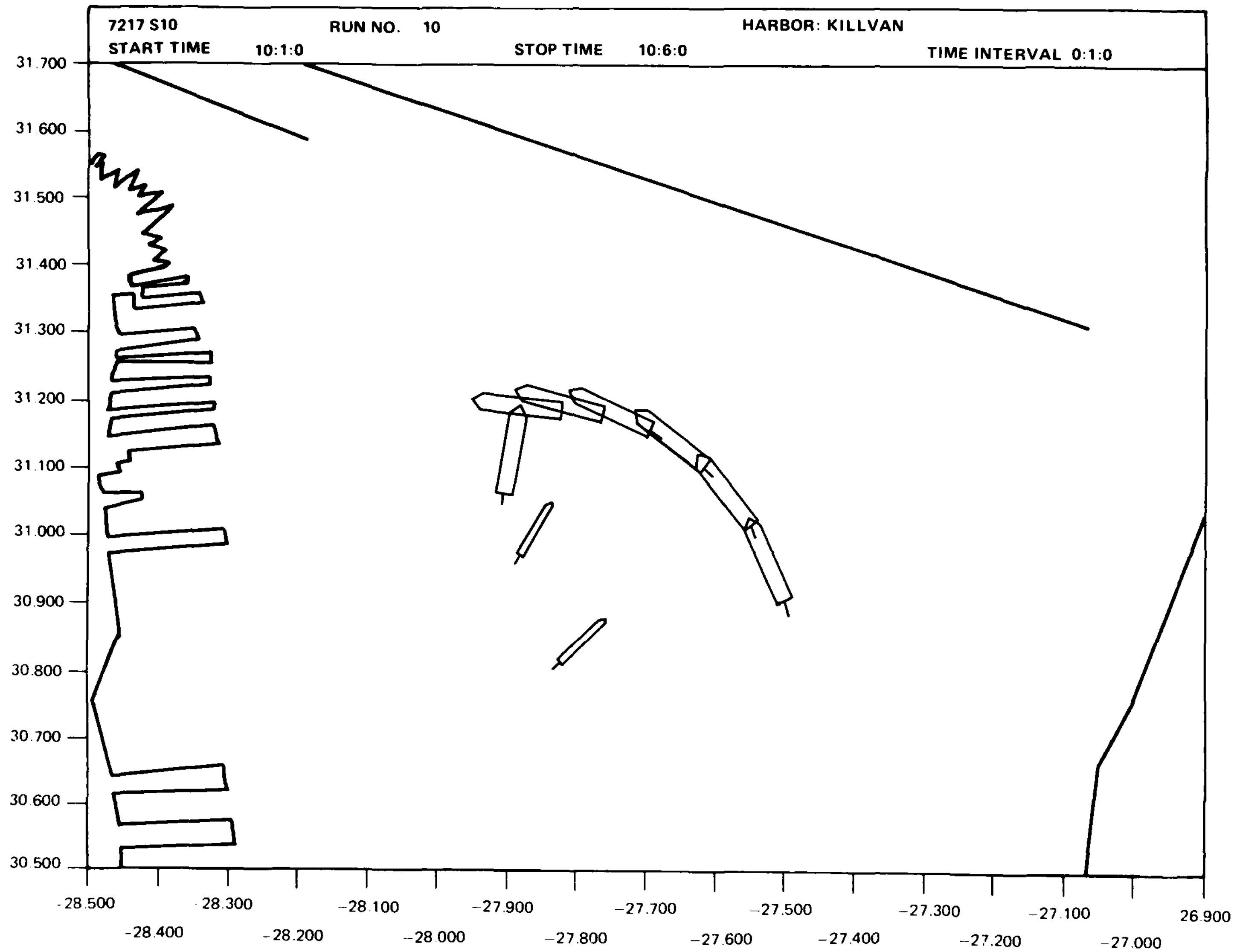

Figure B-20. Track Plots, Pilots, Leg 1, Rudder Failure

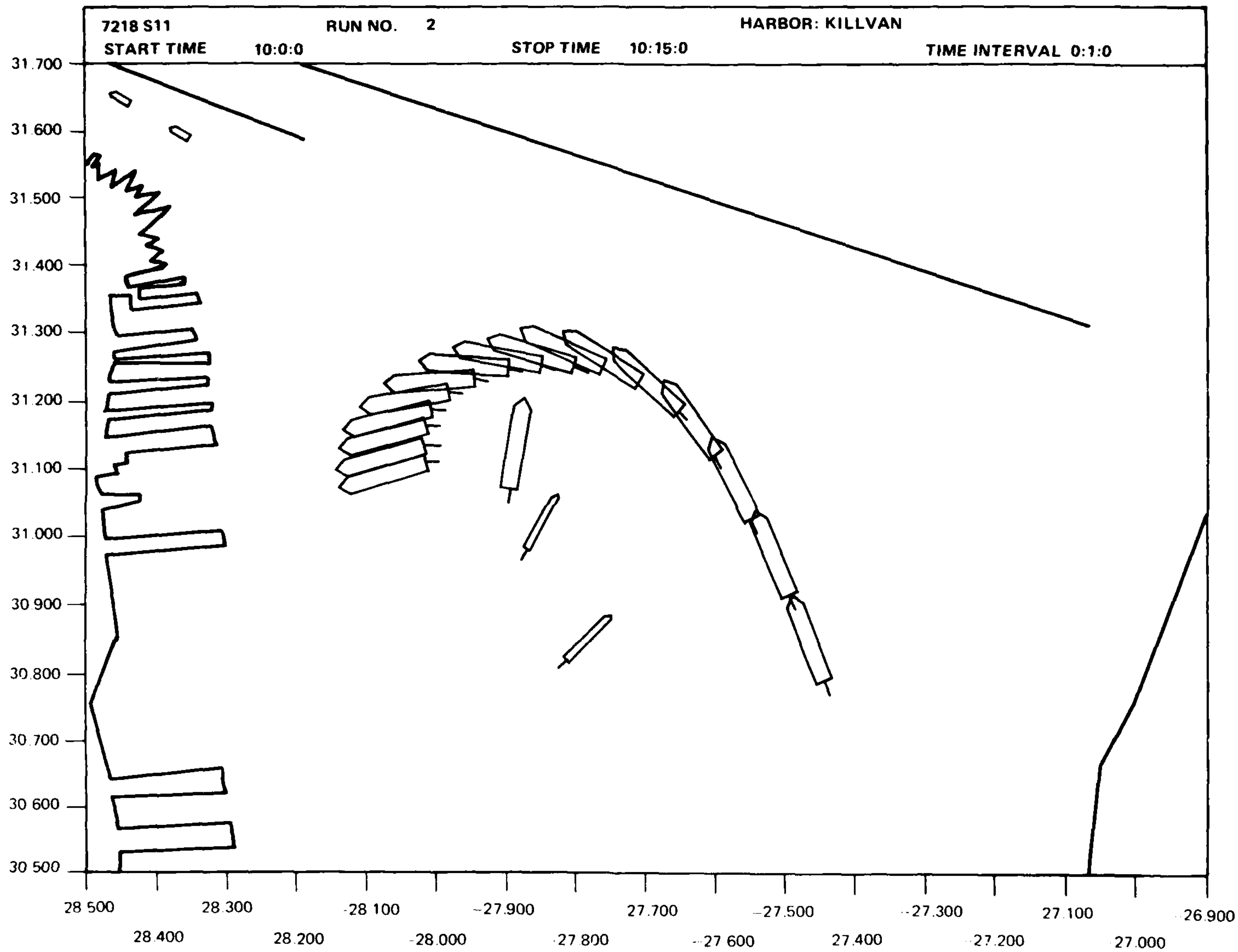

Figure B-21. Track Plots, Pilots, Leg 1, Rudder Failure

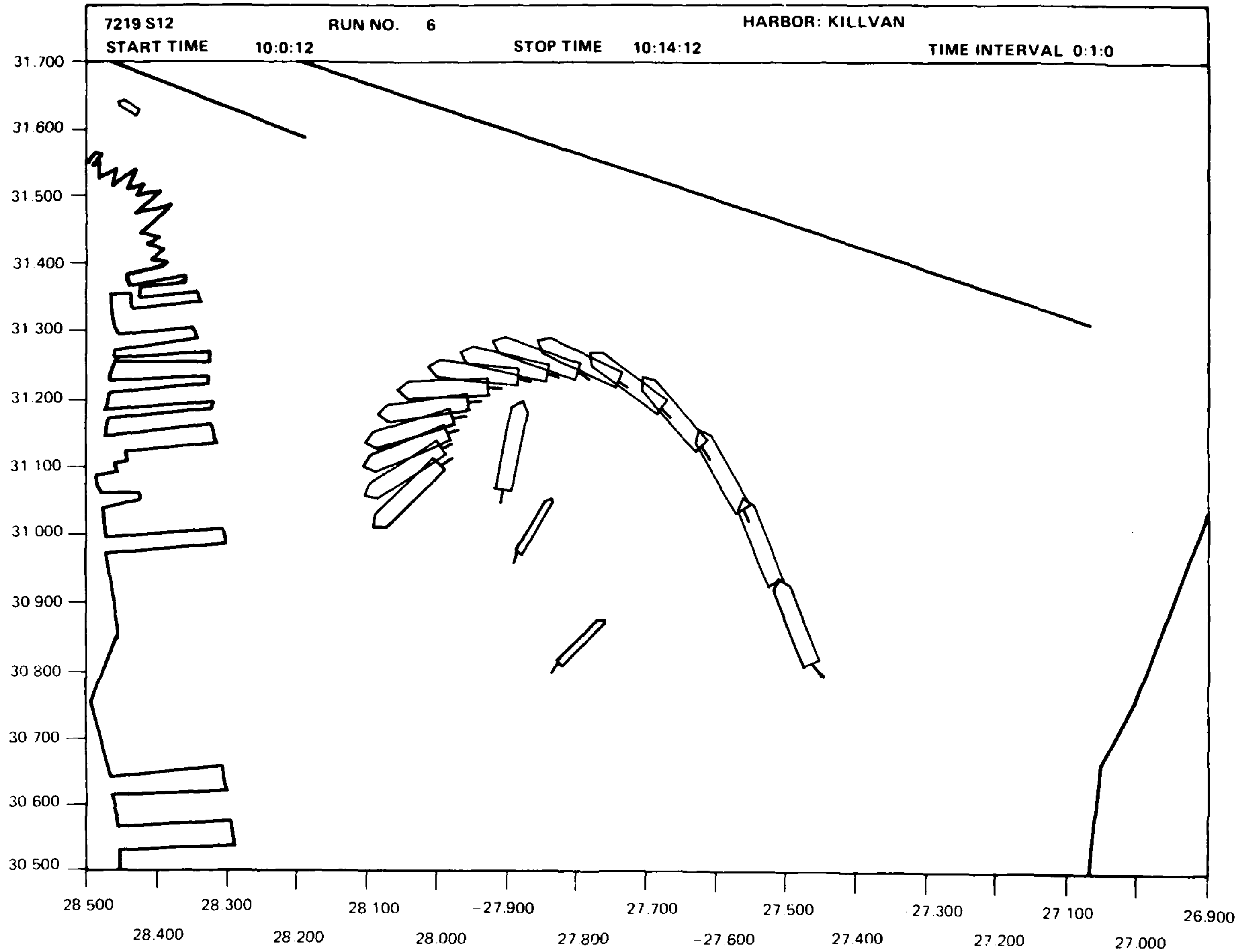

Figure B-22. Track Plots, Pilots, Leg 1, Rudder Failure

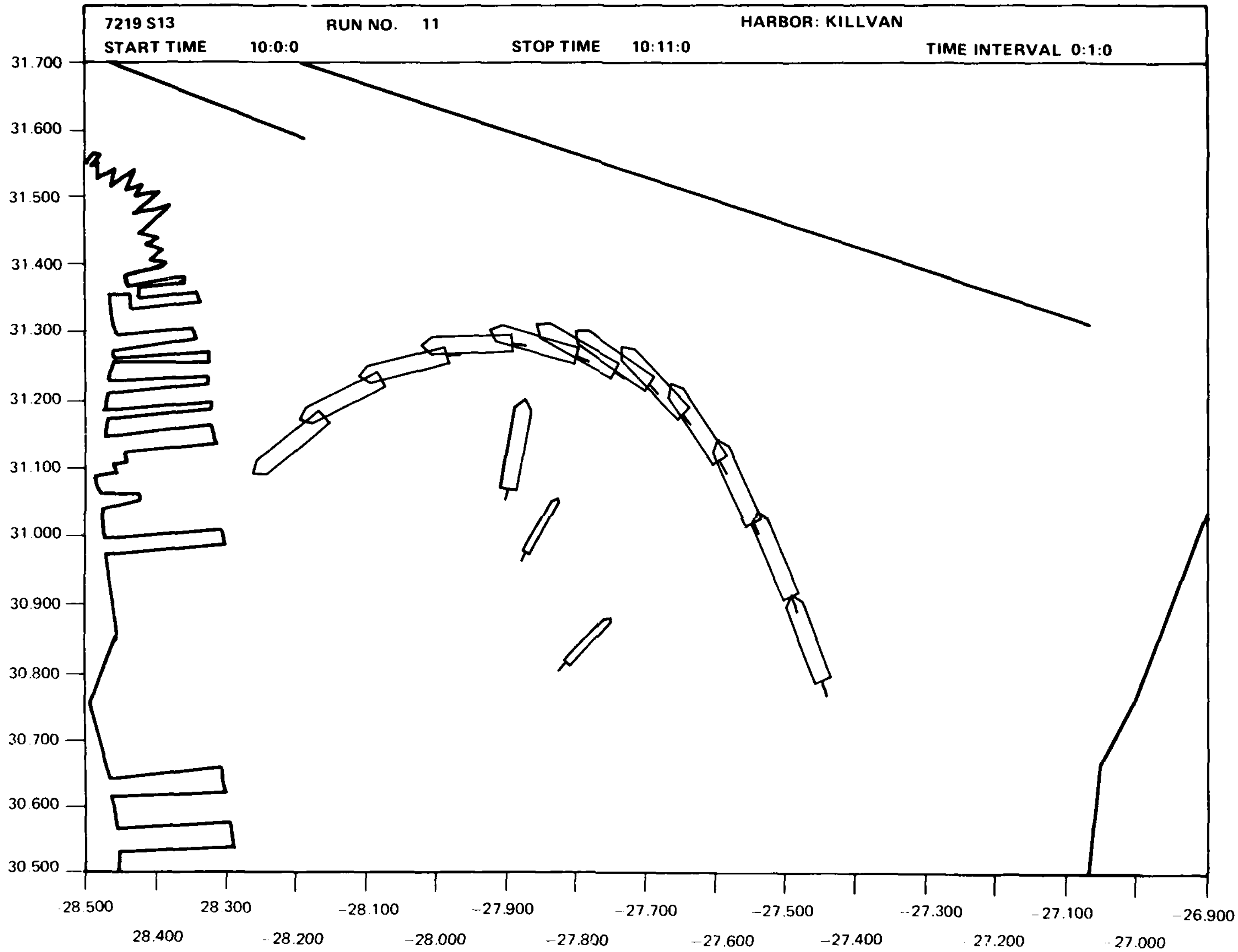

Figure B-23. Track Plots, Pilots, Leg 1, Rudder Failure

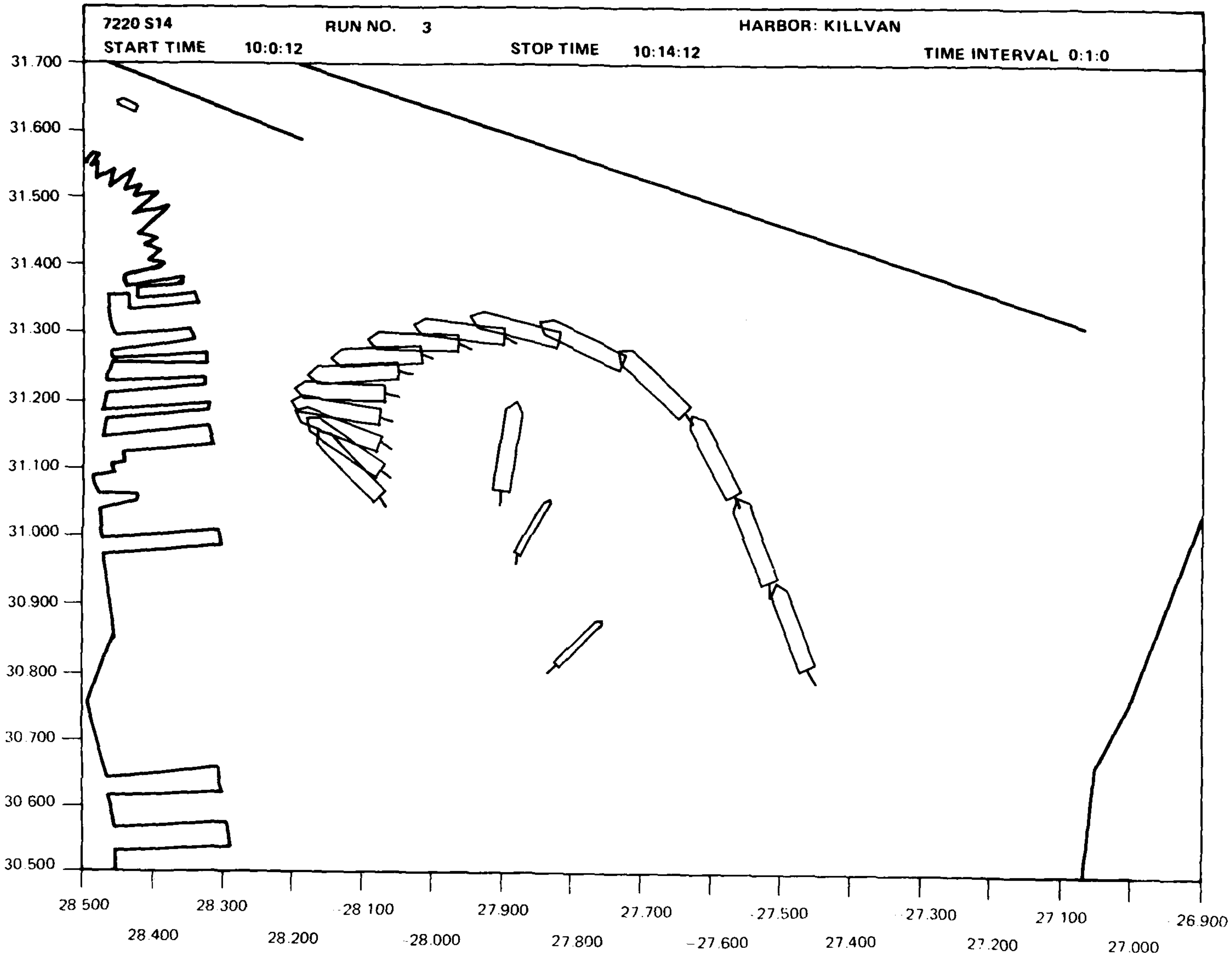

Figure B-24. Track Plots, Pilots, Leg 1, Rudder Failure

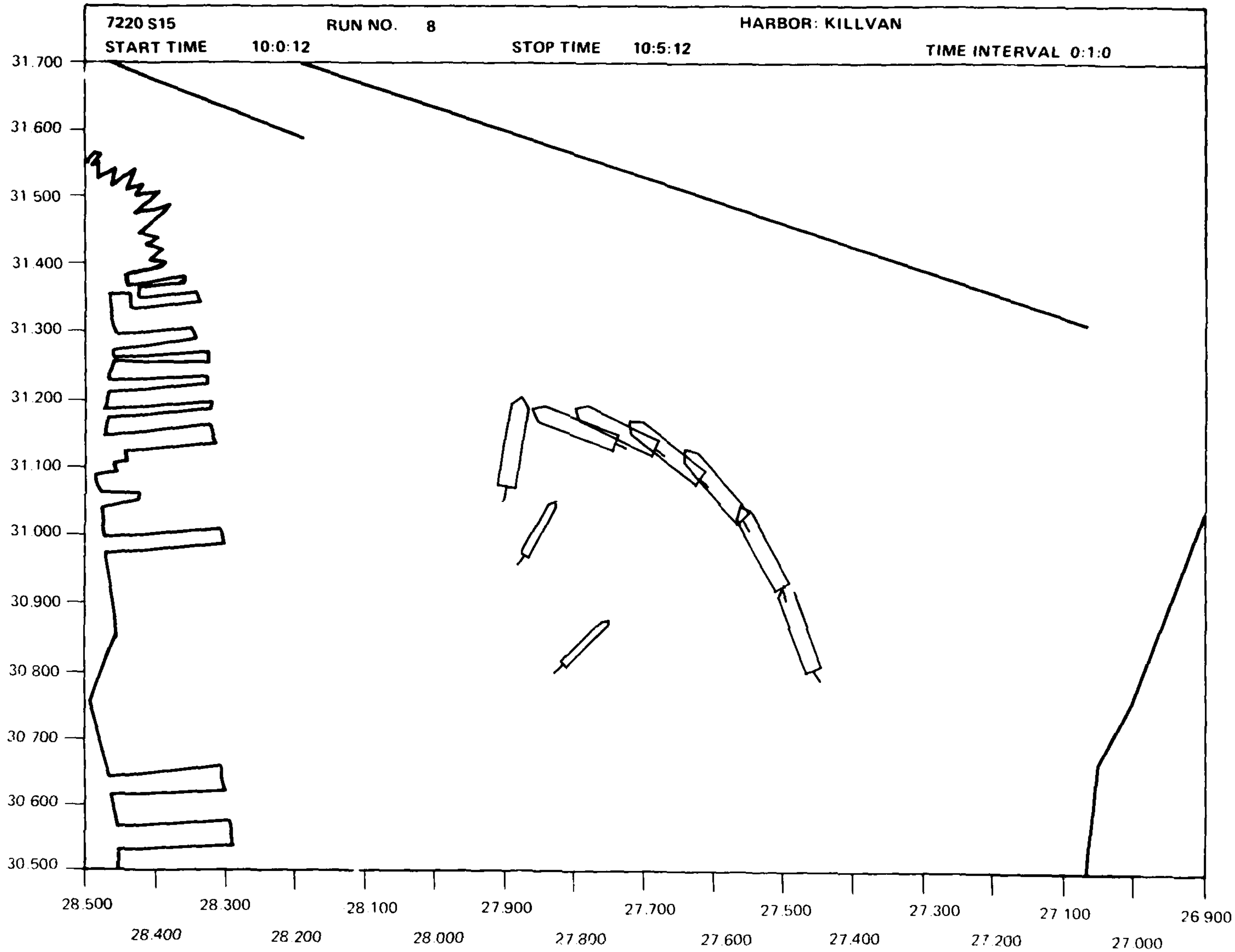

Figure B-25. Track Plots, Pilots, Leg 1, Rudder Failure

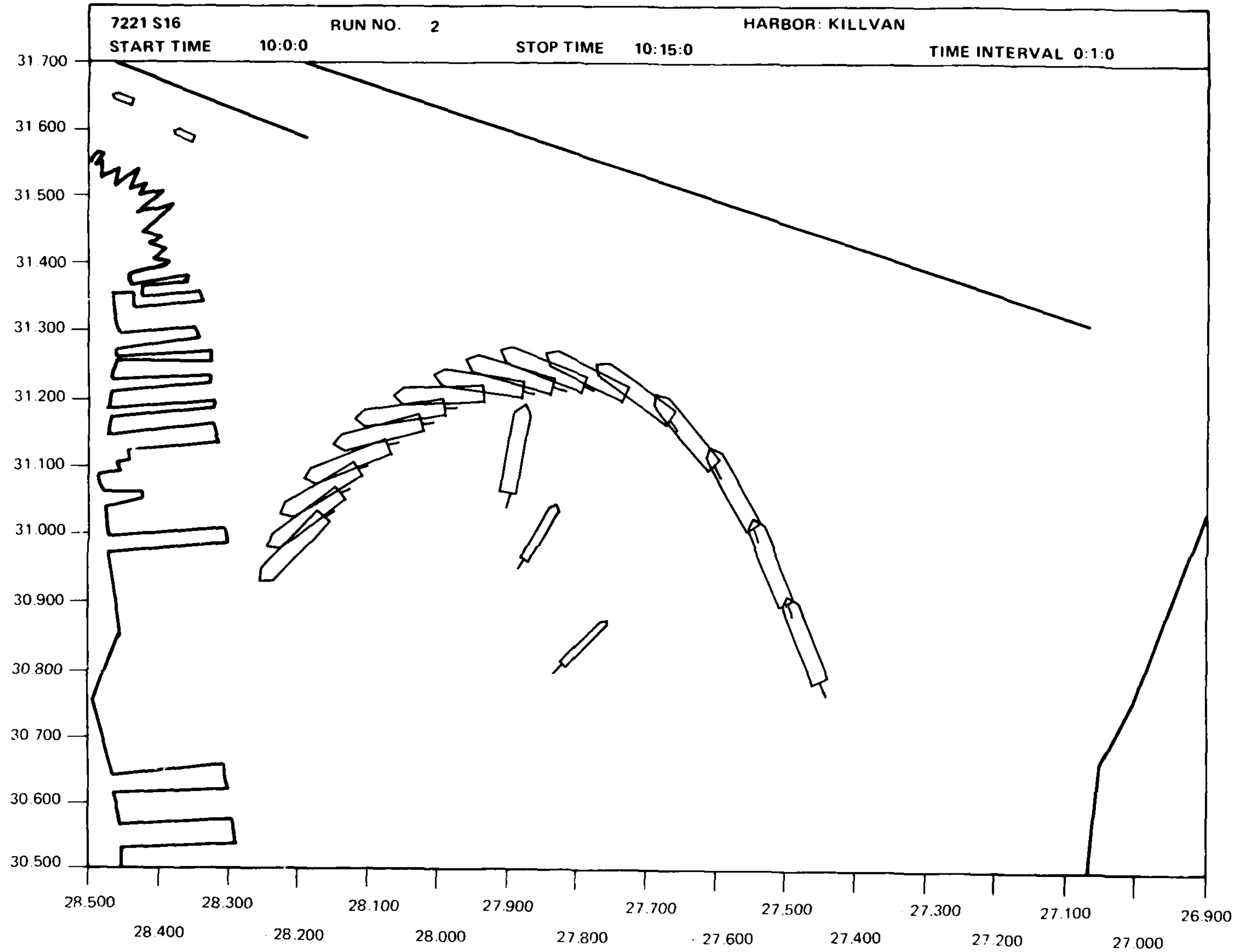

Figure B-26. Track Plots, Pilots, Leg 1, Rudder Failure

AD-A116 536 NATIONAL MARITIME RESEARCH CENTER KINGS POINT NY COM--ETC F/G 5/9
SIMULATORS FOR MARINER TRAINING AND LICENSING. PHASE 3, TASK C.--ETC(U)
MAR 82 K WILLIAMS, A D'AMICO, J GOLDBERG
UNCLASSIFIED CAORF-50-8007-02 USCG-D-15-82 NL

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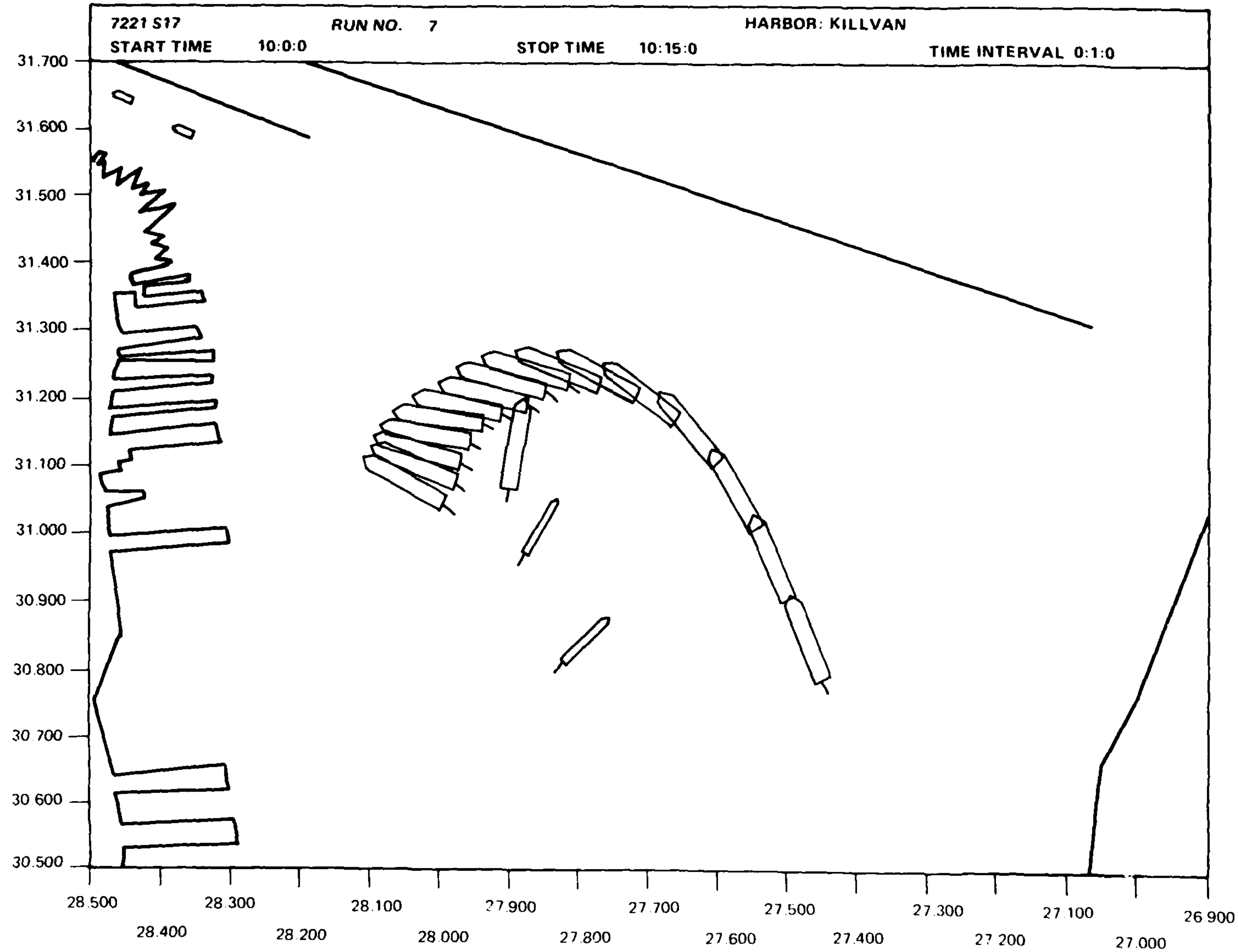

Figure B-27. Track Plots, Pilots, Leg 1, Rudder Failure

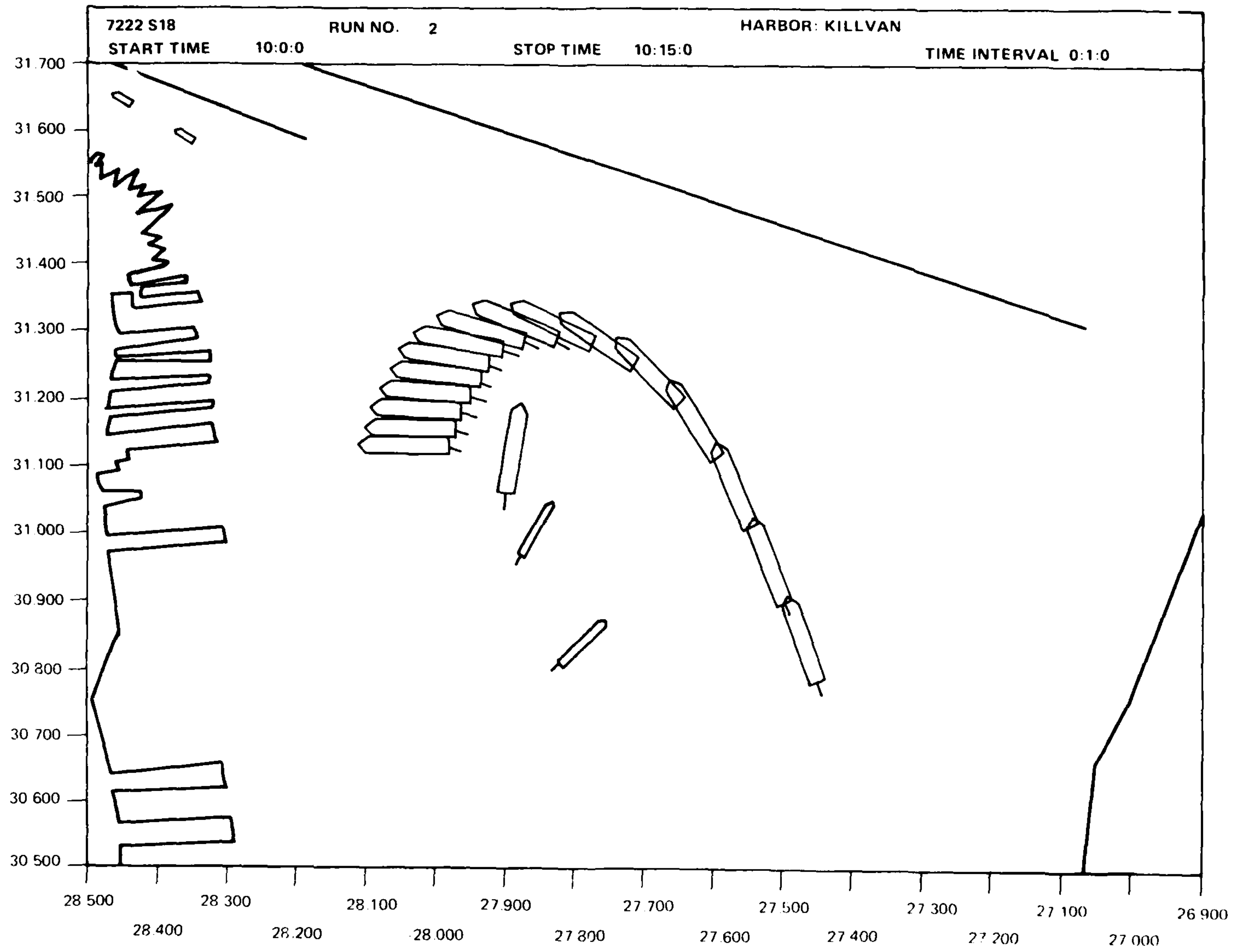

Figure B-28. Track Plots, Pilots, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: CPA (in feet) to Ship 3, Including Collisions

	Masters	Pilots
$\bar{X}$	326.34	188.23
SD	207.99	189.73
90% Confidence Interval	256.57 to 446.18	360.48 to 16

Cutoff Score: > 199.91. Subjects with scores > 199.91 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	9	5
Masters	12	2

χ^2 = (with Yates Correction) = 0.762, not significant

Figure B-29. Summary of Data and Contingency Table, CPA (in feet) to Ship 3 Including Collisions, Leg 1, Rudder Failure

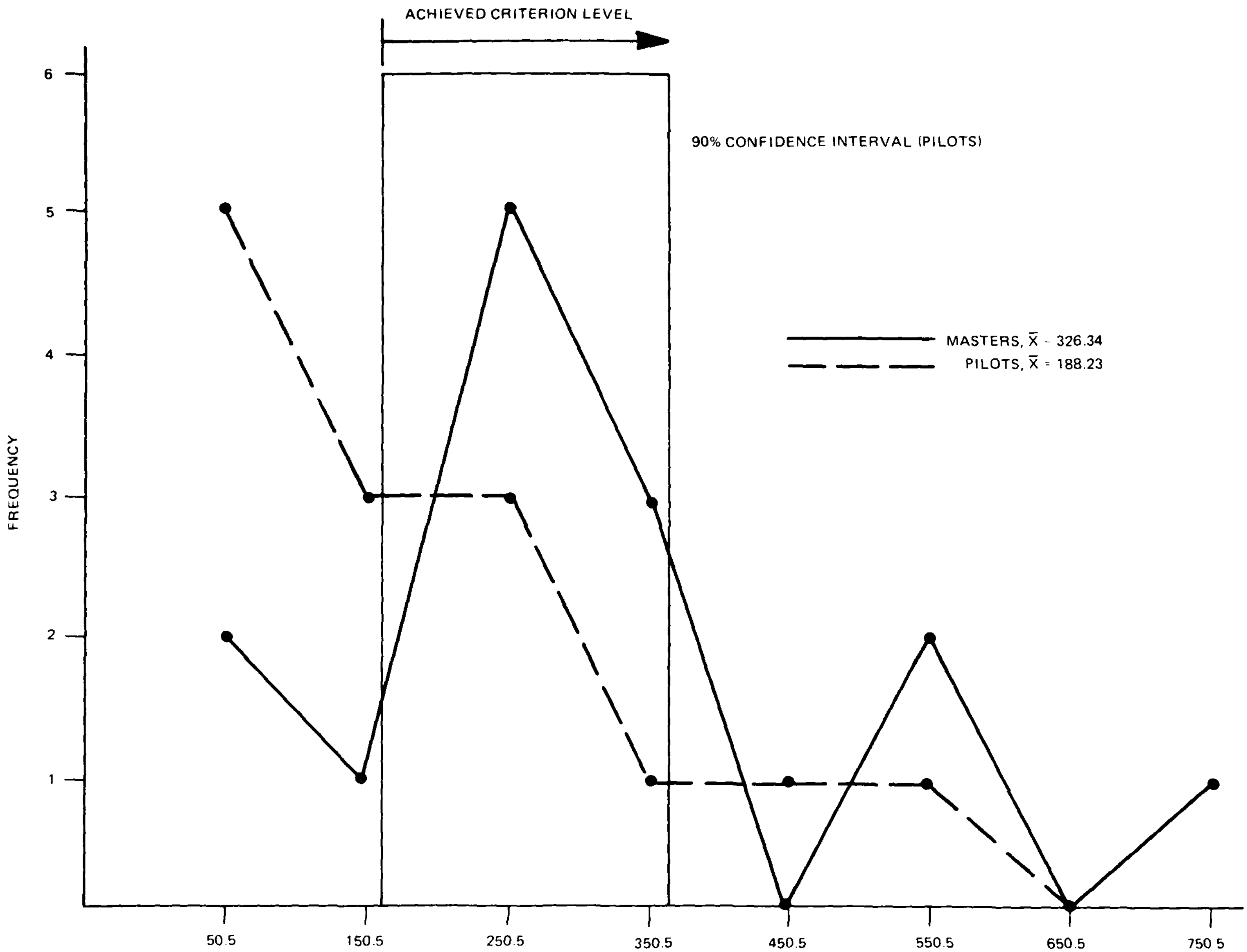

Figure B-30. Frequency Distribution and Confidence Interval, CPA (in feet) to Ship 3 Including Collisions, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: CPA (in feet) to Ship 3, Excluding Collisions

	Masters	Pilots
$\bar{X}$	351.38	263.7
SD	193.13	172.9
90% Confidence Interval	256.57 to 446.18	166.91 to 360.48

Cutoff Score: > 166.91. Subjects with scores > 166.91 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	7	3
Masters	12	1

χ^2 = (with Yates Correction) = 0.713, not significant

Figure B-31. Summary of Data and Contingency Table, CPA (in feet) to Ship 3 Excluding Collisions, Leg 1, Rudder Failure

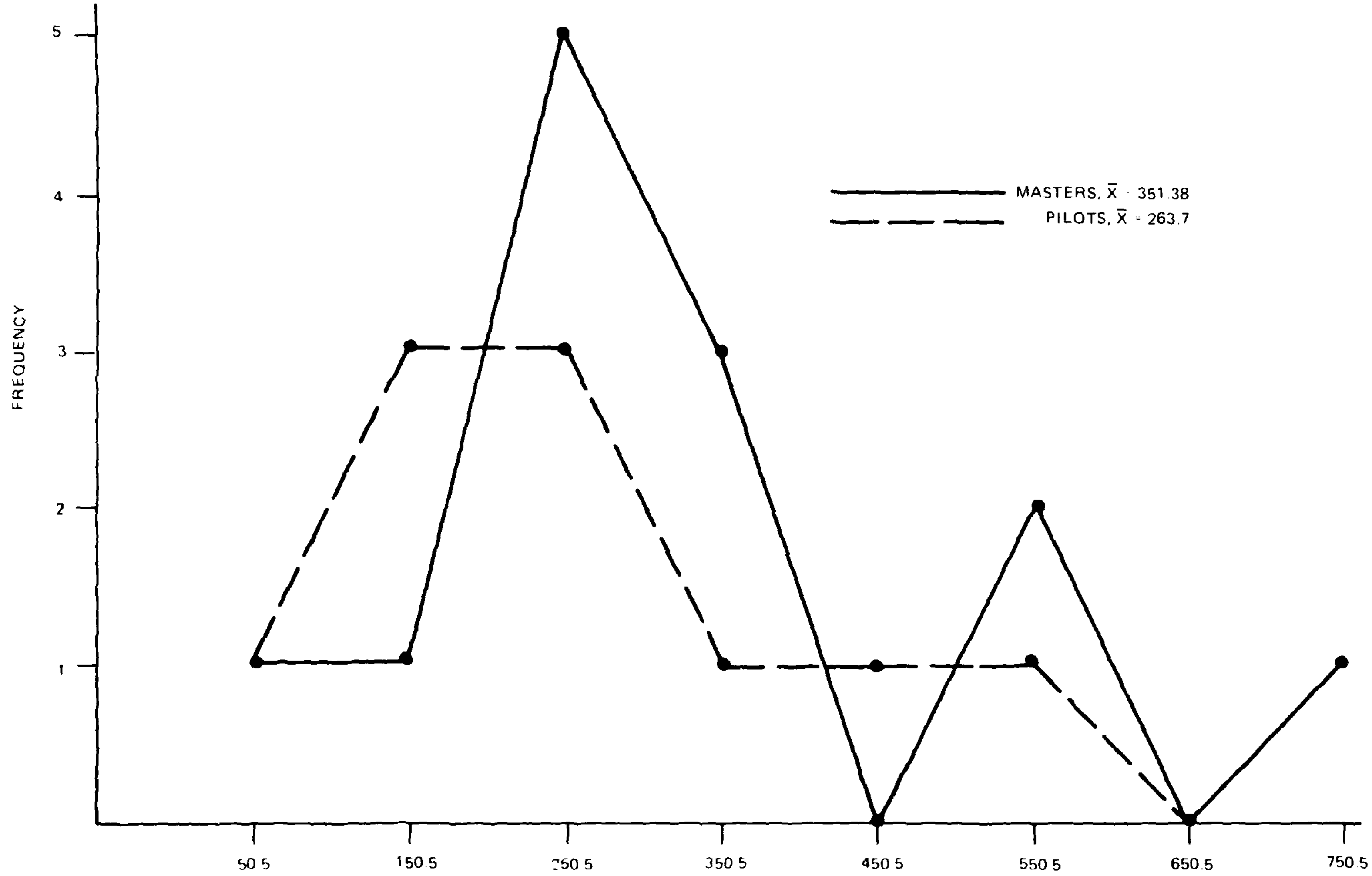

Figure B-32. Frequency Distribution, CPA (in feet) to Ship 3 Excluding Collisions, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: CPA (in feet) to Ship 4

	Masters	**Pilots**
$\bar{X}$	1075.93	922.82
SD	217.58	202.69
90% Confidence Interval	1178.85 to 973.00	1018.70 to 826.94

Cutoff Score: Are considered not to have achieved criterion.

	Achieved Criterion	**Not Achieved Criterion**
Pilots	7	3
Masters	12	1

χ^2 = (with Yates Correction) = 0.762, not significant

Figure B-33. Summary of Data and Contingency Table, CPA (in feet) to Ship 4, Leg 1, Rudder Failure

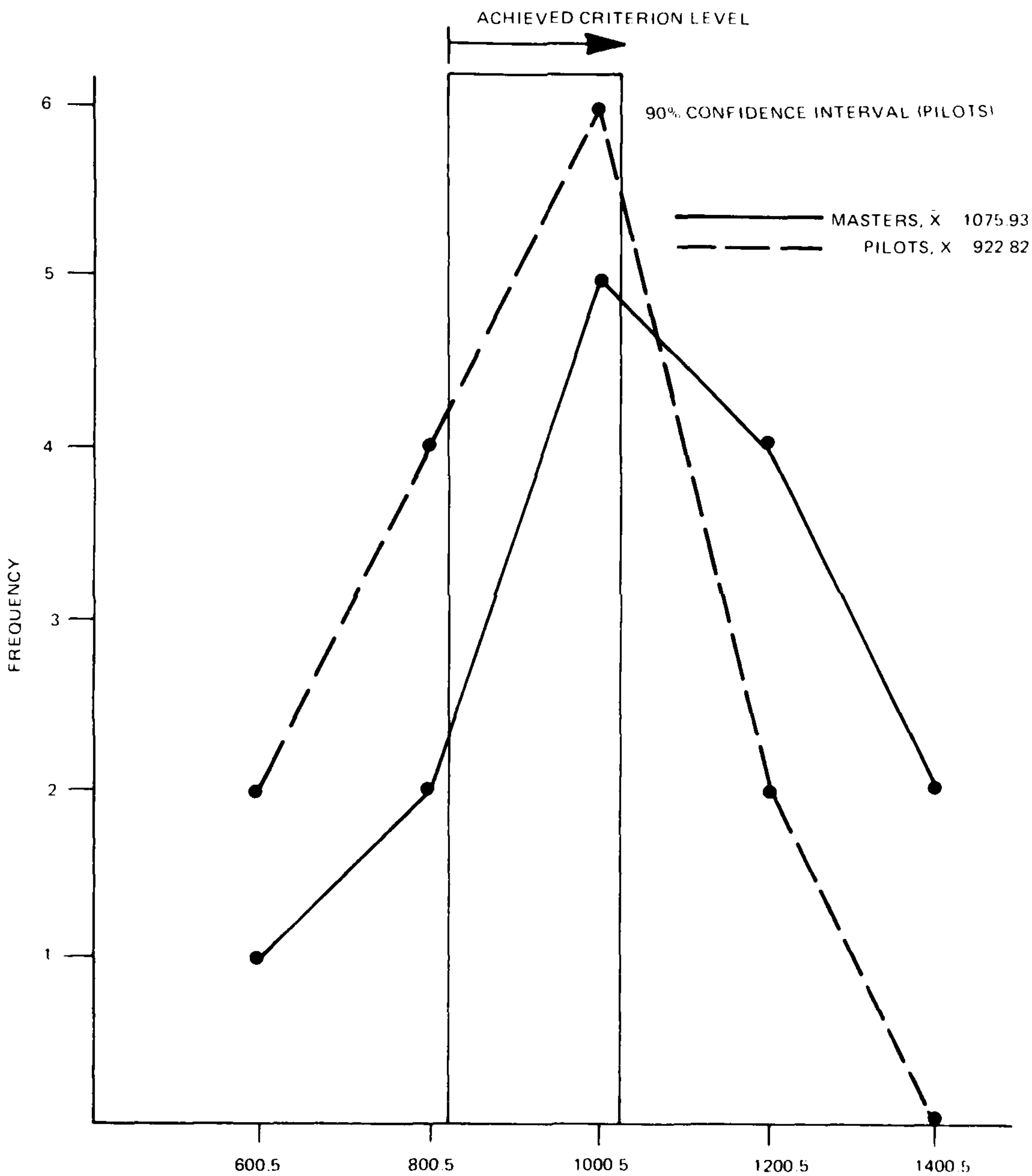

Figure B-34. Frequency Distribution and Confidence Interval, CPA (in feet) to Ship 4, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: Time (in seconds) to Reduce Speed Over Ground to < 2 Knots Including Collisions

	Masters	Pilots
$\bar{X}$	520.14	437.14
SD	133.35	136.96
90% Confidence Interval	583.22 to 457.05	501.92 to 372.36

Cutoff Score: > 501.92. Subjects with scores > 501.92 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	6	8

$\chi^2 = 3.74, p < 0.10$

χ^2 = (with Yates Correction) = 2.39, not significant

Figure B-35. Summary of Data and Contingency Table, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Including Collisions, Leg 1, Rudder Failure

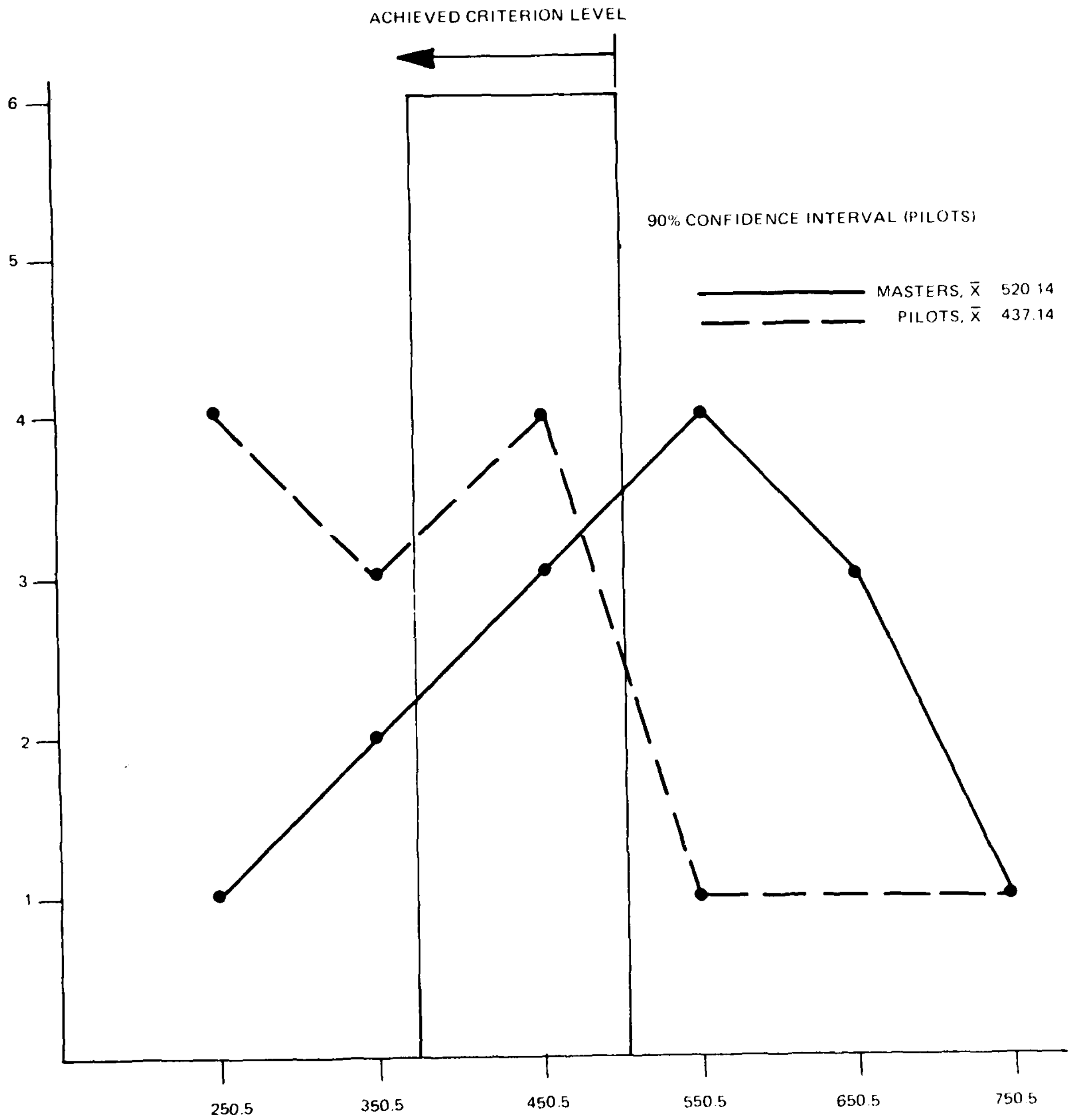

Figure B-36. Frequency Distribution and Confidence Interval, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Including Collisions, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: Time (in seconds) to Reduce Speed Over Ground to < 2 Knots, Excluding Collisions

	Masters	Pilots
$\bar{X}$	525.83	474.54
SD	86.88	131.05
90% Confidence Interval	570.11 to 481.54	544.47 to 404.68

Cutoff Score: > 544.47. Subjects with scores > 544.47 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	8	3
Masters	7	5

χ^2 = 0.524, not significant

χ^2 = (with Yates Correction)

Figure B-37. Summary of Data and Contingency Table, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Excluding Collisions, Leg 1, Rudder Failure

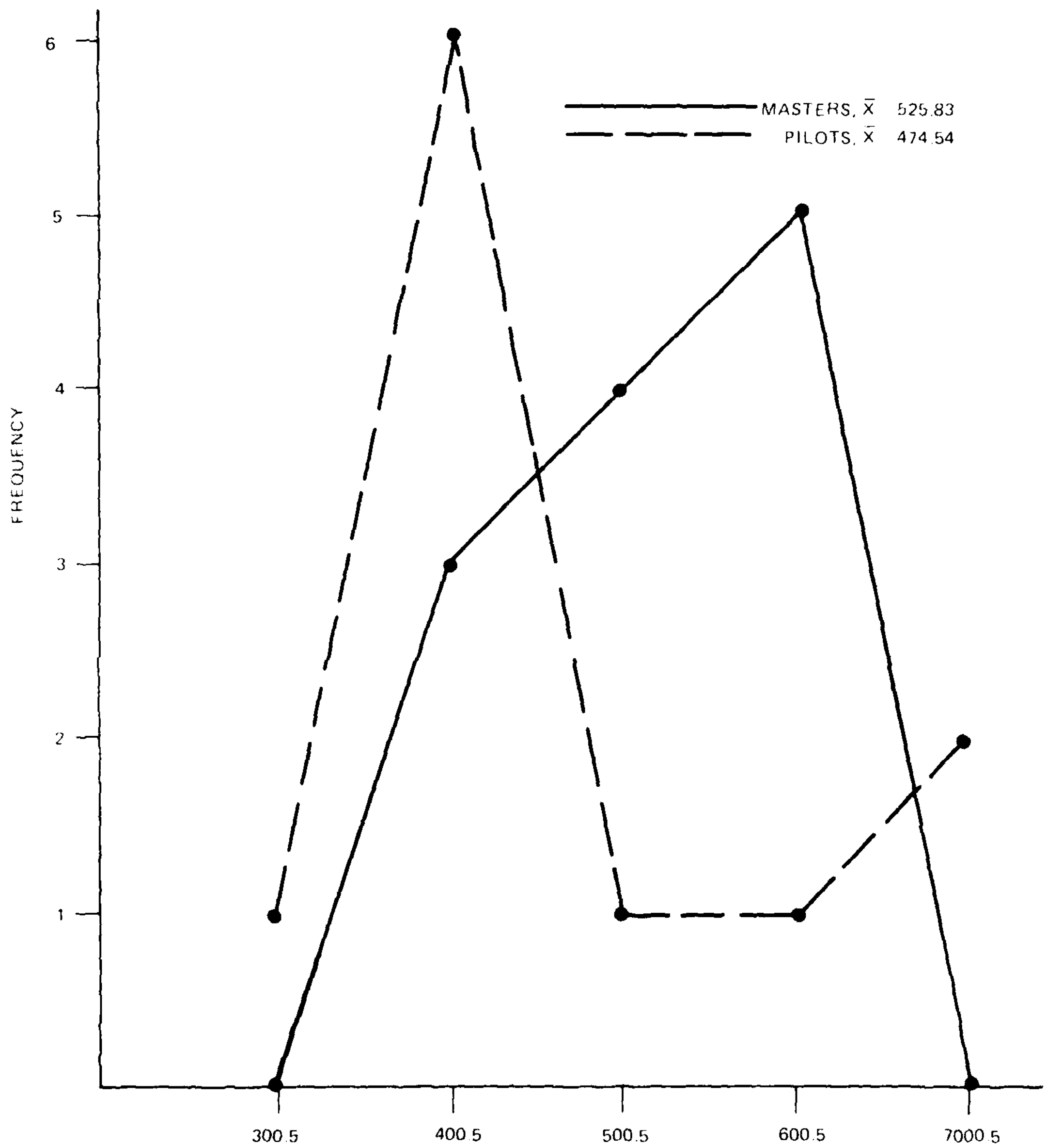

Figure B-38. Frequency Distribution, Time (in seconds) to Reduce Speed Over Ground to Less Than 2 Knots Excluding Collisions, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: *Time to Reduce Rate of Turn < 0.1°/Sec., Including Collisions*

	Masters	Pilots
$\bar{X}$	229.7	205.7
SD	85.1	66.3
90% Confidence Interval	269.95 to 189.45	237.06 to 174.33

Cutoff Score: > 237.06. Subjects with scores > 237.06 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	8	6

χ^2 = (with Yates Correction) = 0.655, not significant

Figure B-39. Summary of Data and Contingency Table, *Time (in seconds)* to Reduce Rate of Turn to More Than 0.1°/Second Including Collisions, Leg 1, Rudder Failure

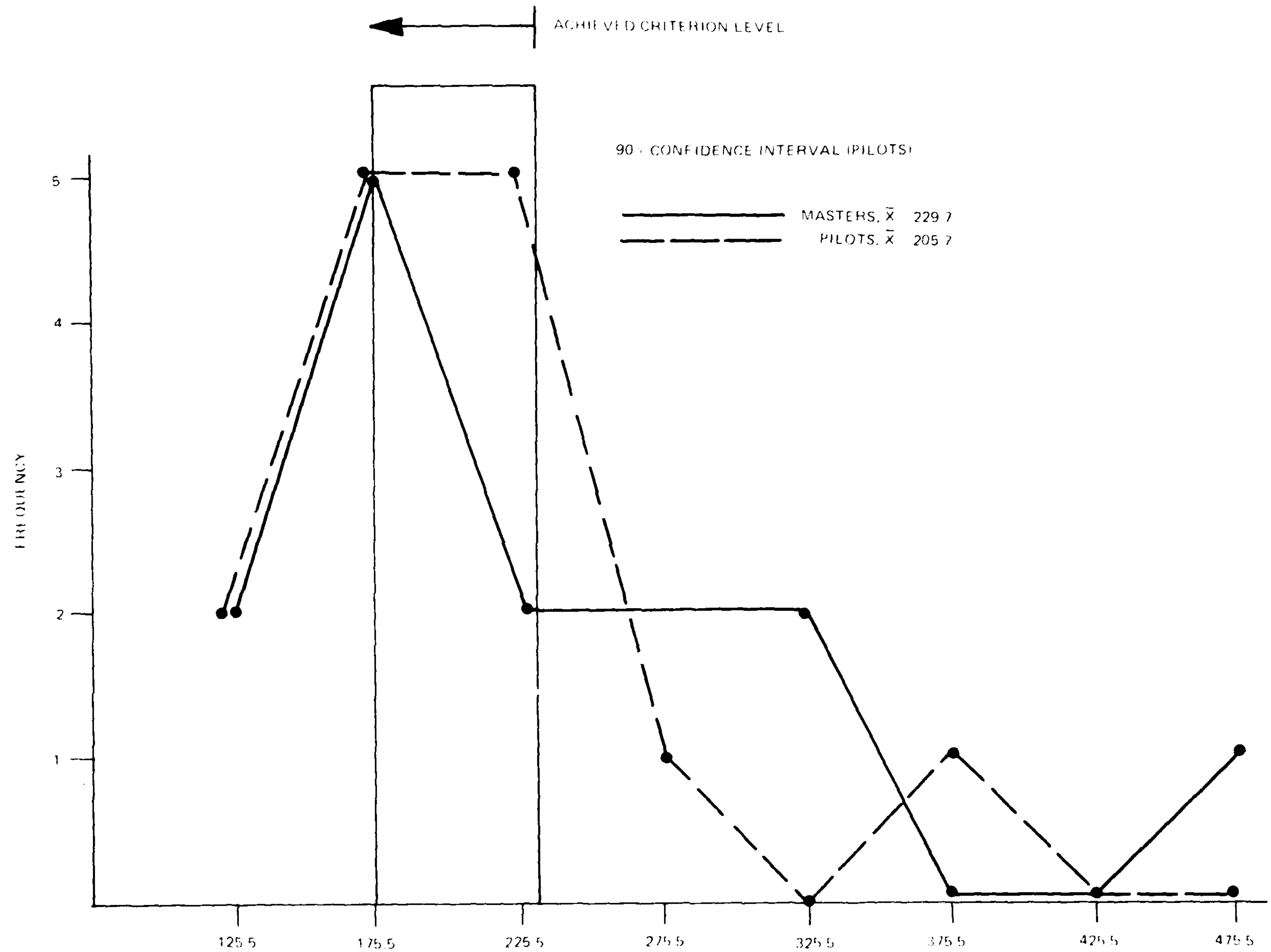

Figure B-40. Frequency Distribution, Time (in seconds) to Reduce Rate of Turn to More Than 0.1 /Second Including Collisions, Leg 1, Rudder Failure

TRAINING OBJECTIVE: Rudder Failure

PERFORMANCE MEASURE: Time to Reduce Rate of Turn < 0.1 /Sec., Excluding Collisions

	Masters	Pilots
X	217.0	207.6
SD	56.85	74.63
90% Confidence Interval	175.20 to 258.71	165.80 to 249.37

Cutoff Score: > 249.37. Subjects with scores > 249.37 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	8	2
Masters	8	4

χ^2 (with Yates Correction) = 0.047, not significant

Figure B-41. Summary of Data and Contingency Table, Time (in seconds) to Reduce Rate of Turn to More Than 0.1°/Second Excluding Collisions, Leg 1, Rudder Failure

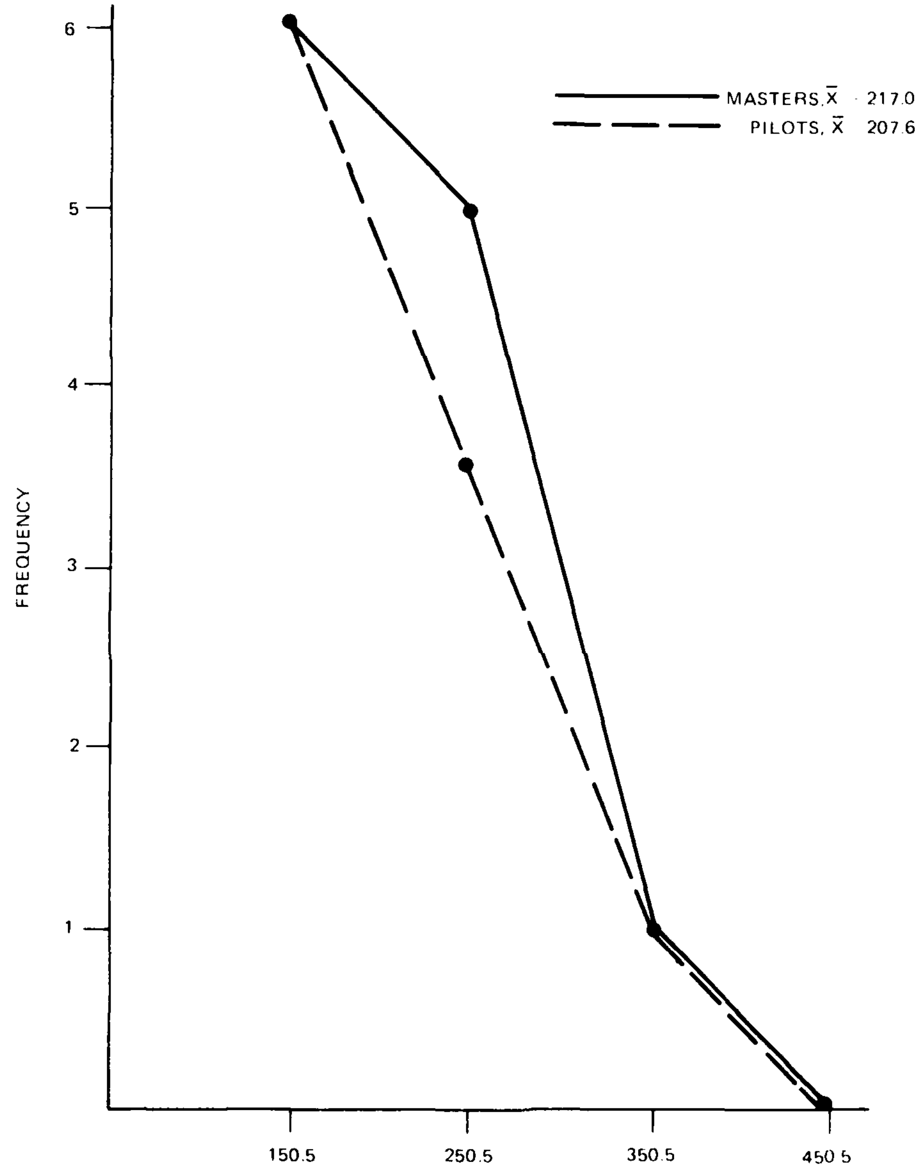

Figure B-42. Frequency Distribution, Time (in seconds) to Reduce Rate of Turn to More Than 0.1° /Second Excluding Collisions, Leg 1, Rudder Failure

		Rudder	RPM Ahead	RPM Astern	Thruster
	$\bar{x}$	75.8	74.79	38.91	17.95
Masters	S.D.	30.40	25.76	21.07	23.28
	n	4	14	11	14
	$\bar{x}$	51.5	73.64	38.17	16.29
Pilots	S.D.	42.13	27.96	19.22	16.71
	n	6	14	12	14
	t*	0.987	0.112	0.088	0.217
	df	8	26	21	26

*All comparisons of means for Masters and Pilots are not significant.

Figure B-43. Percent of Rudder, Engine RPM, and Thruster Remaining, Leg 1, Rudder Failure

APPENDIX C

PERFORMANCE MEASURES APPENDICES

LEG 2 – 51° TURN

TRAINING OBJECTIVE: NEGOTIATING A 51° TURN WITH PASSING SHIP EFFECTS

LIST OF ILLUSTRATIONS

Number	
C-1 to C-14	Track Plots, Masters, Leg 2, 51° Turn and Leg 3, 129° Turn
C-15 to C-28	Track Plots, Pilots, Leg 2, 51° Turn and Leg 3, 129° Turn
C-29	Summary of Data and Contingency Table, CPA (in feet) to Ship 3, Leg 2, 51° Turn
C-30	Frequency Distribution, CPA (in feet) to Ship 3, Leg 2, 51° Turn
C-31	Summary of Data and Contingency Table, Maximum Swept Path (in feet), Leg 2, 51° Turn
C-32	Frequency Distribution, Maximum Swept Path (in feet), Leg 2, 51° Turn
C-33	Summary of Data and Contingency Table, Average Swept Path (in feet), Leg 2, 51° Turn
C-34	Frequency Distribution Maximum Ratio Swept Path, Leg 2, 51° Turn
C-35	Summary of Data and Contingency Table, Maximum Ratio Swept Path, Leg 2, 51° Turn
C-36	Frequency Distribution, Maximum Ratio Swept Path, Leg 2, 51° Turn
C-37	Summary of Data and Contingency Table, Average Ratio Swept Path, Leg 2, 51° Turn
C-38	Frequency Distribution, Average Ratio Swept Path, Leg 2, 51° Turn
C-39	Right Rudder Commands by Location, Leg 2, 51° Turn
C-40	Midship Rudder Commands by Location, Leg 2, 51° Turn
C-41	Left Rudder Commands by Location, Leg 2, 51° Turn
C-42	Percent of Rudder, Engine, and Thruster Remaining, Leg 2, 51° Turn

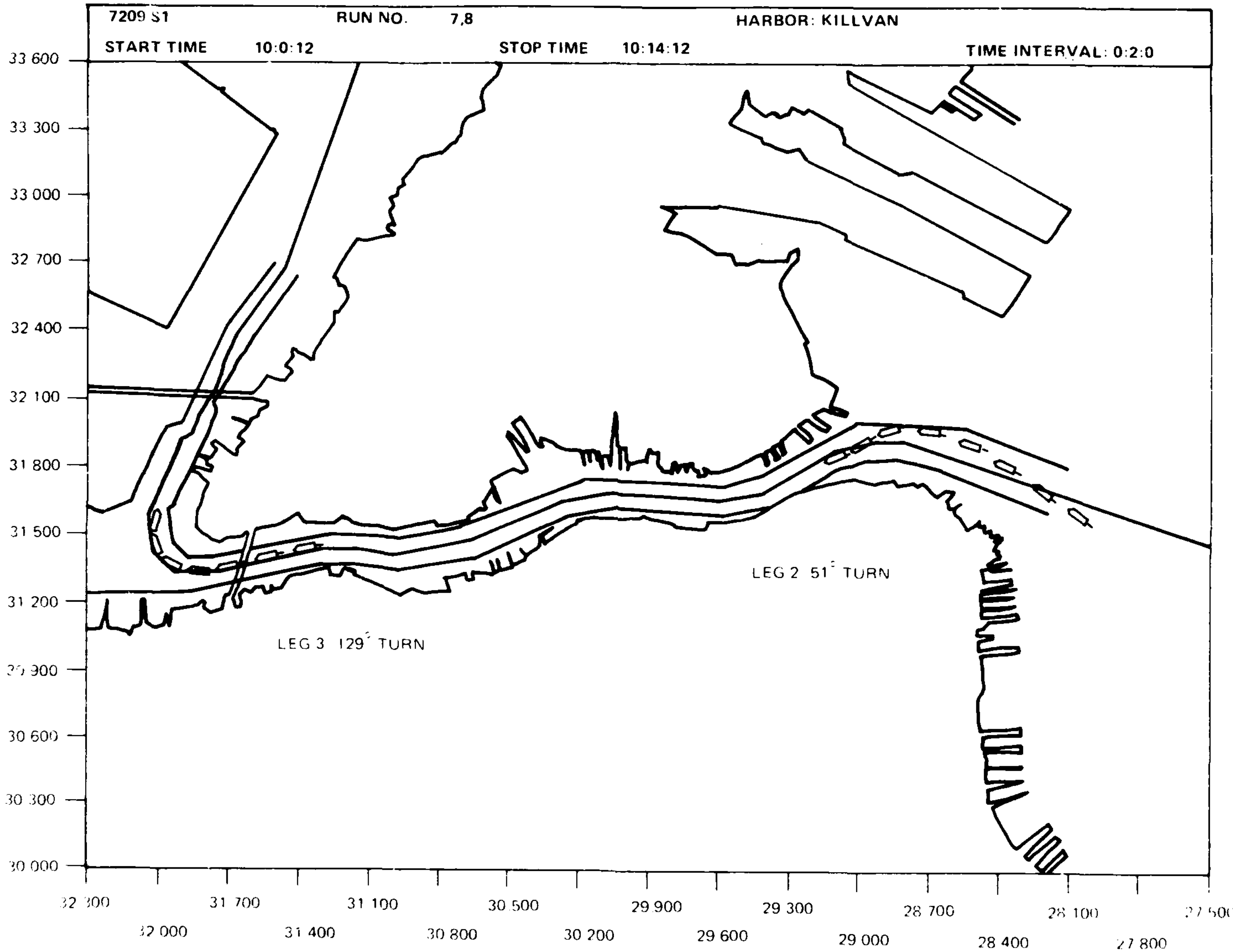

Figure C-1. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

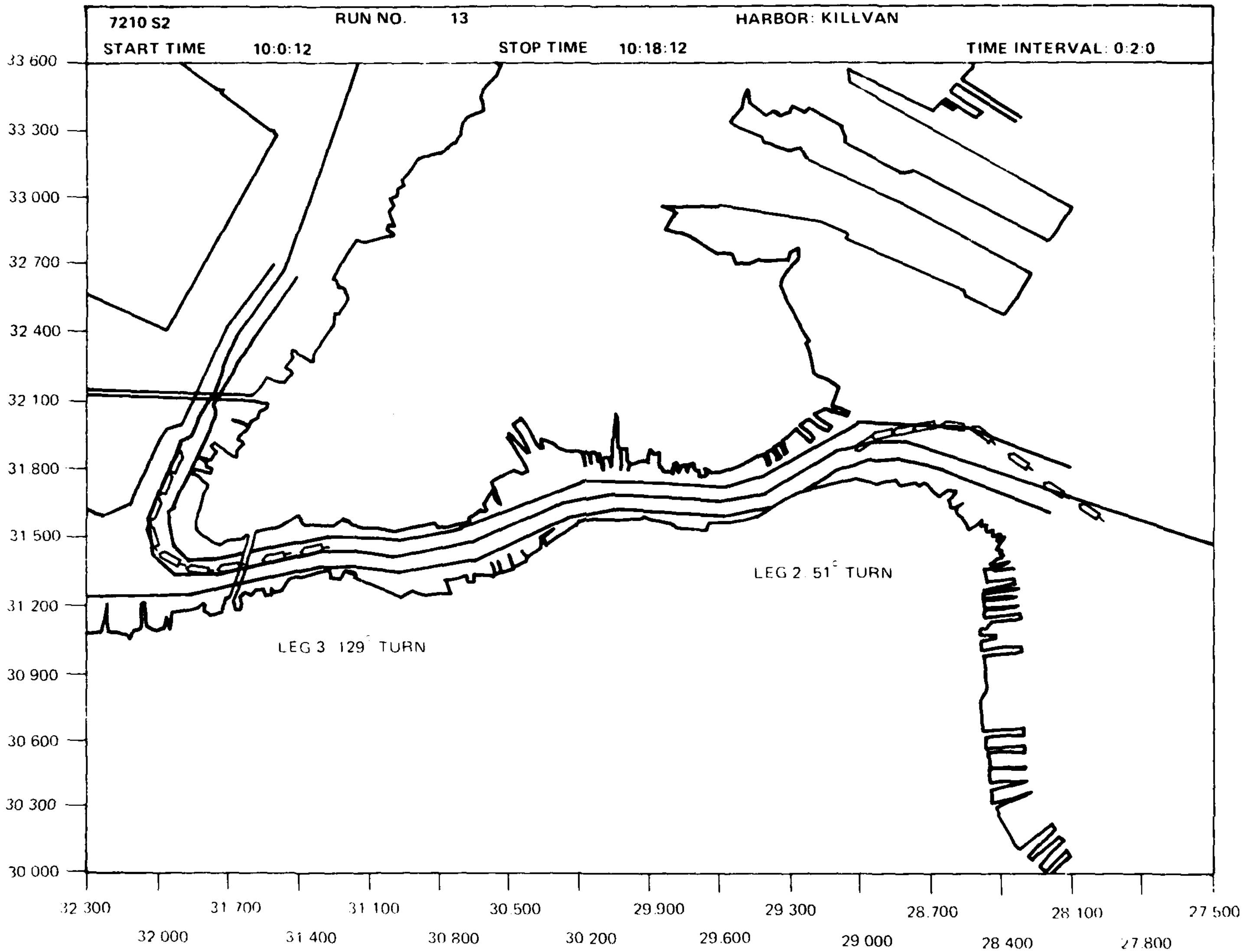

Figure C-2. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

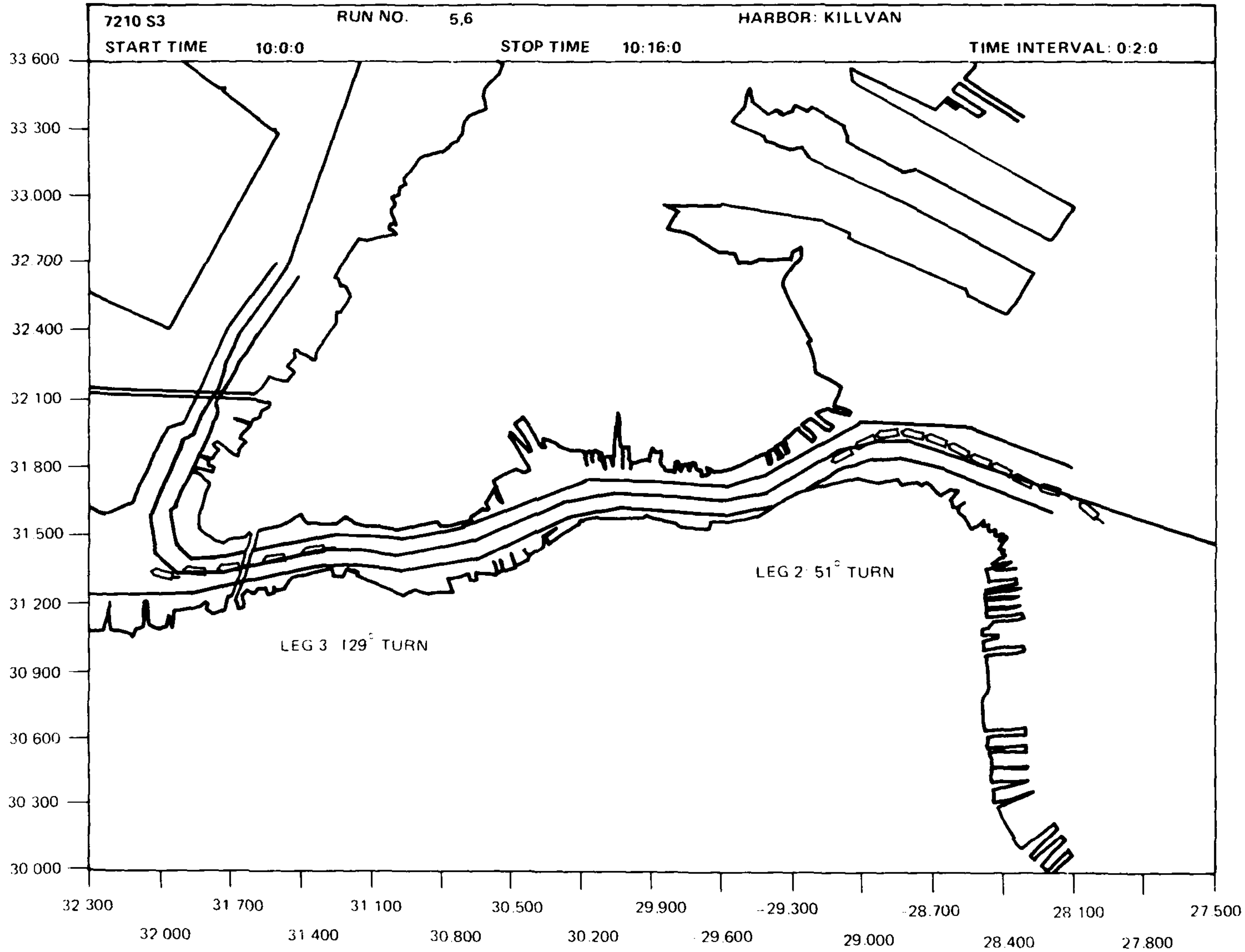

Figure C-3. Track Plots, Masters, Leg 2, 51° Turn and Leg 3, 129° Turn

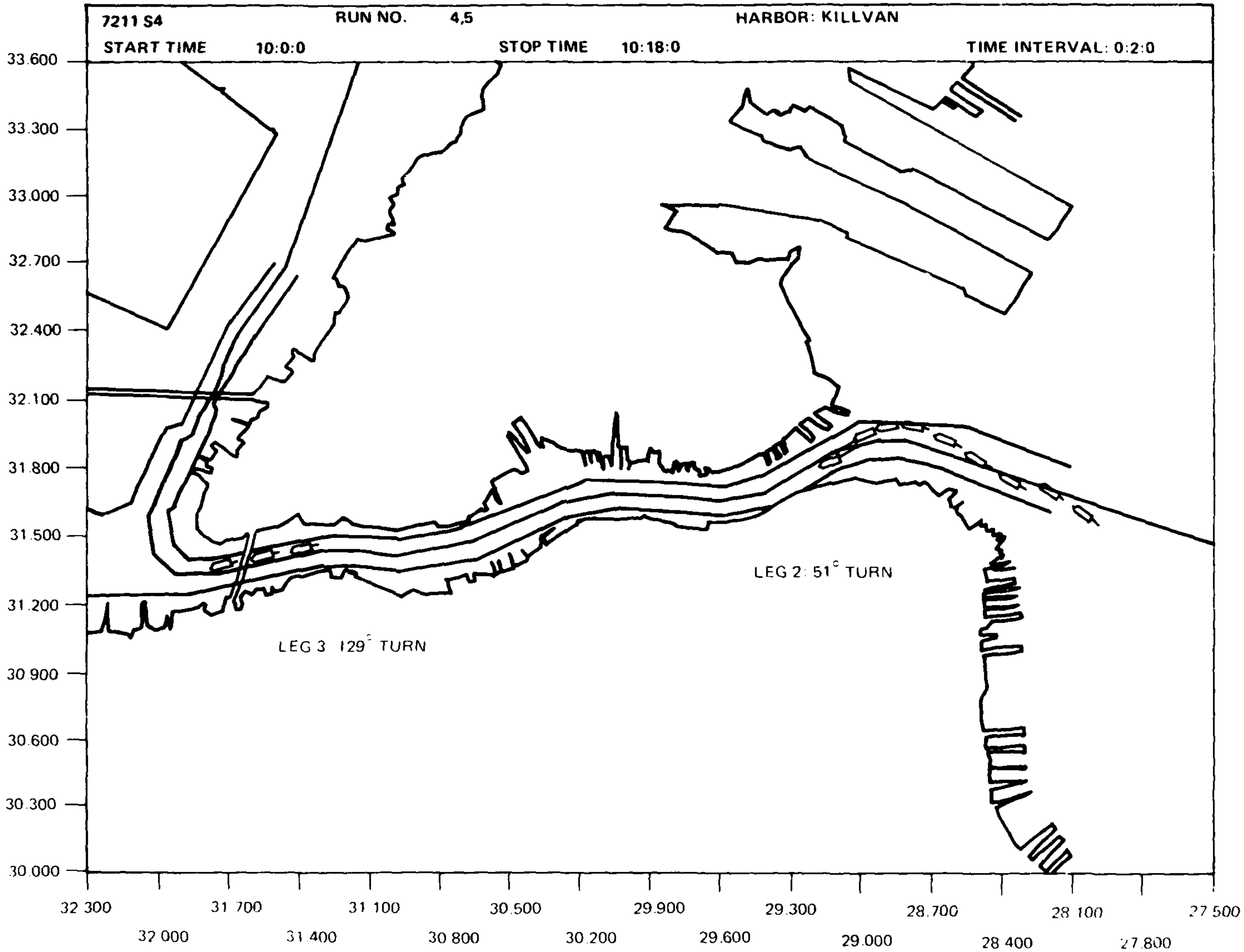

Figure C-4. Track Plots, Masters, Leg 2, 51° Turn and Leg 3, 129° Turn

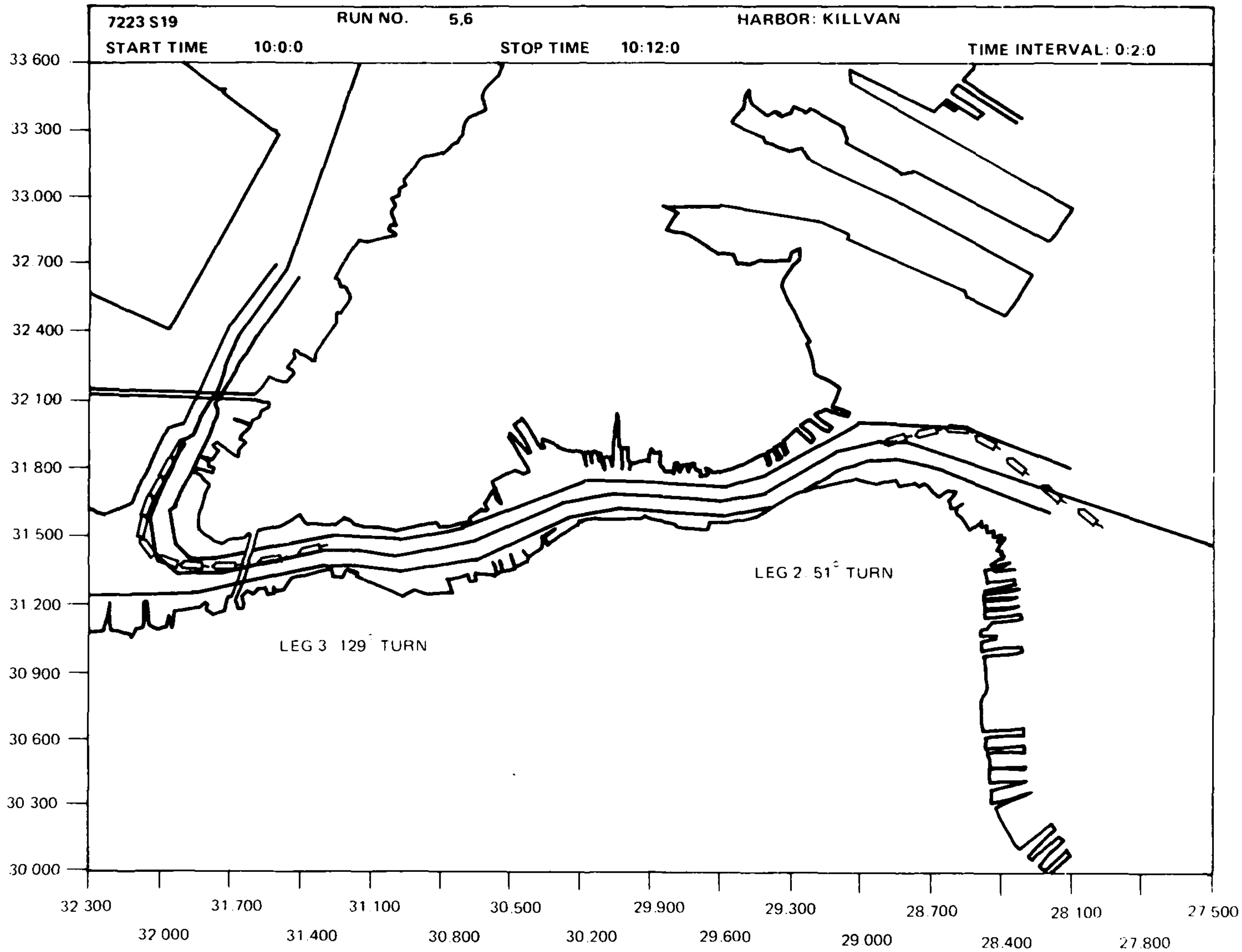

Figure C-5. Track Plots, Masters, Leg 2, 51° Turn and Leg 3, 129° Turn

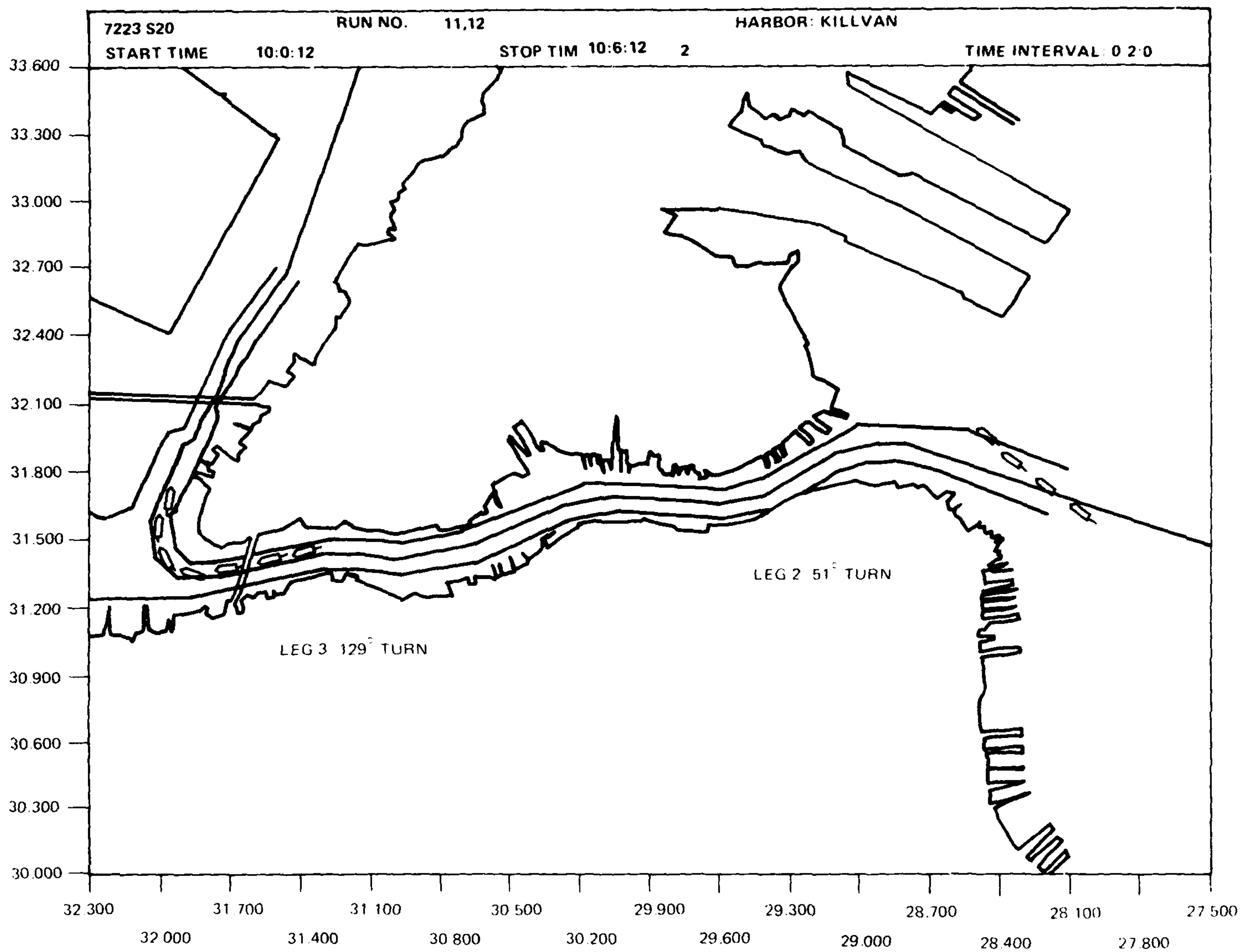

Figure C-6. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

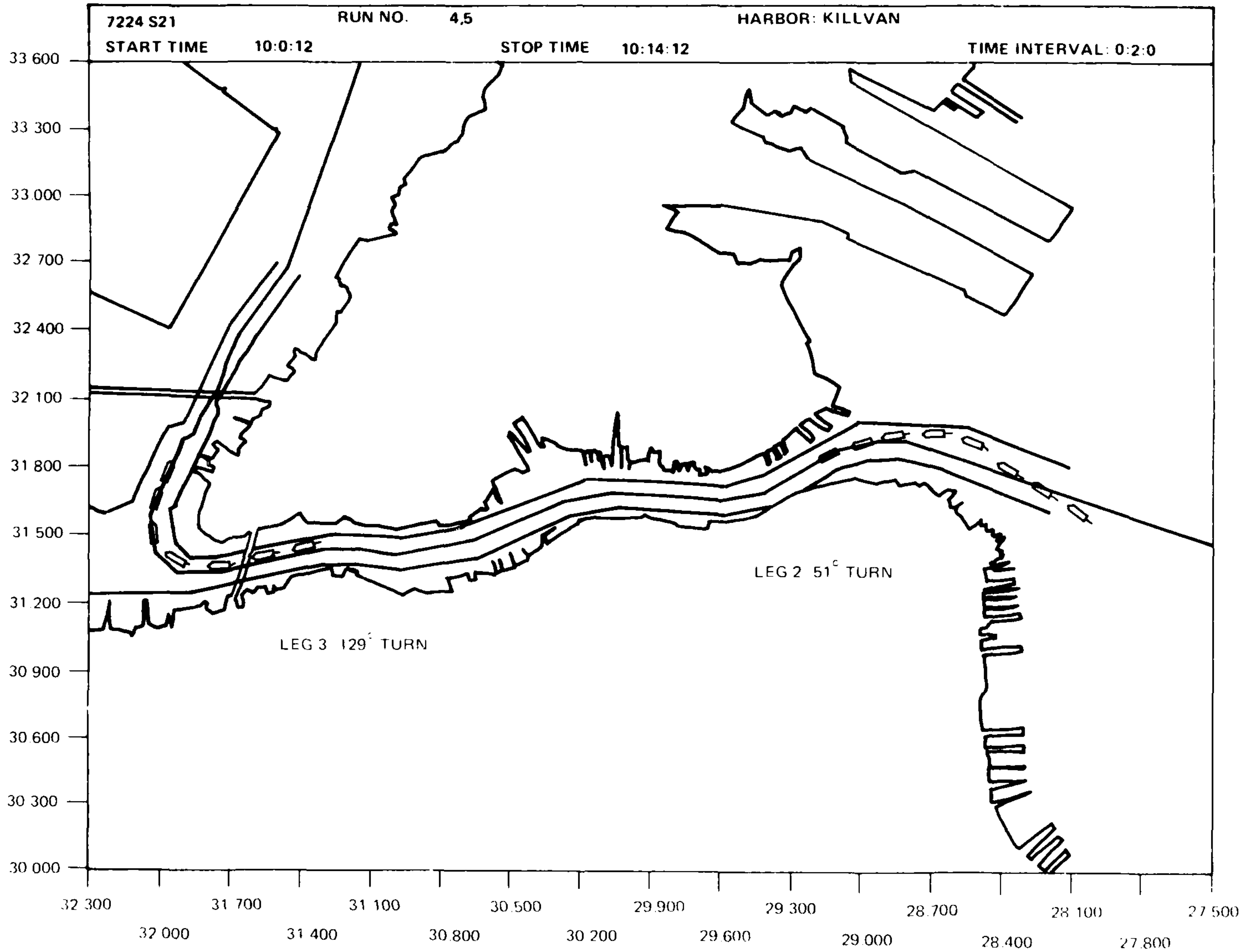

Figure C-7. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

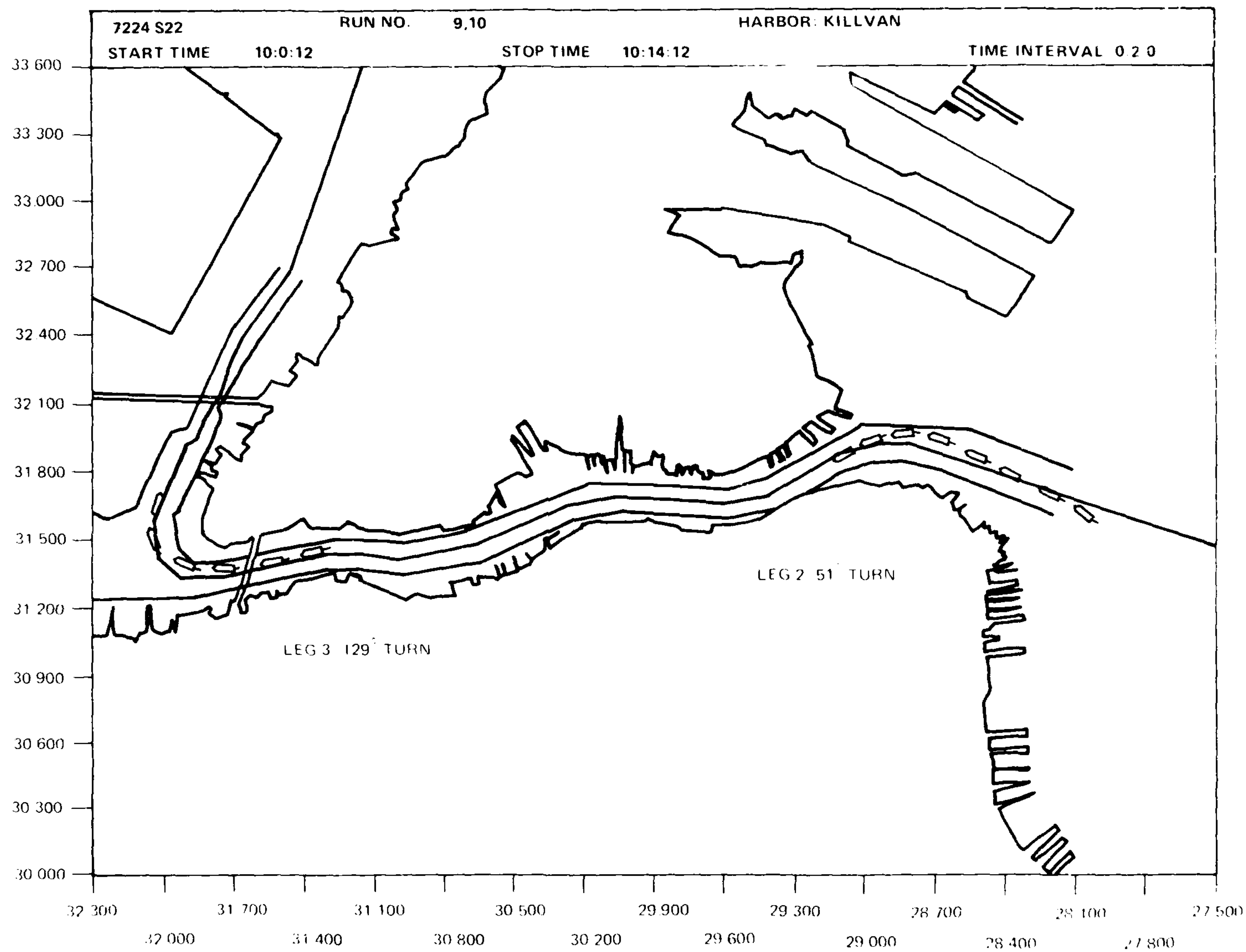

Figure C 8. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

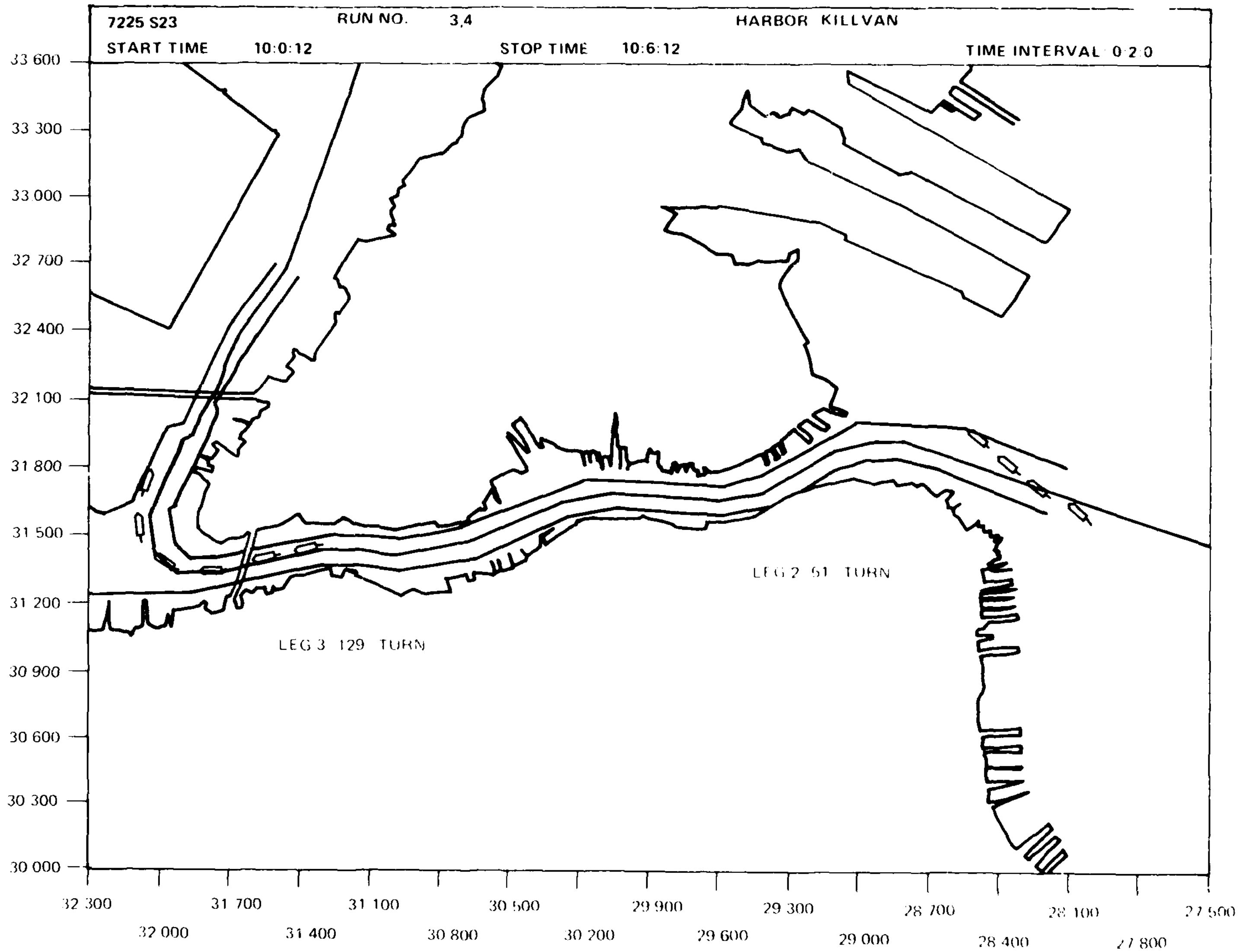

Figure C-9. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

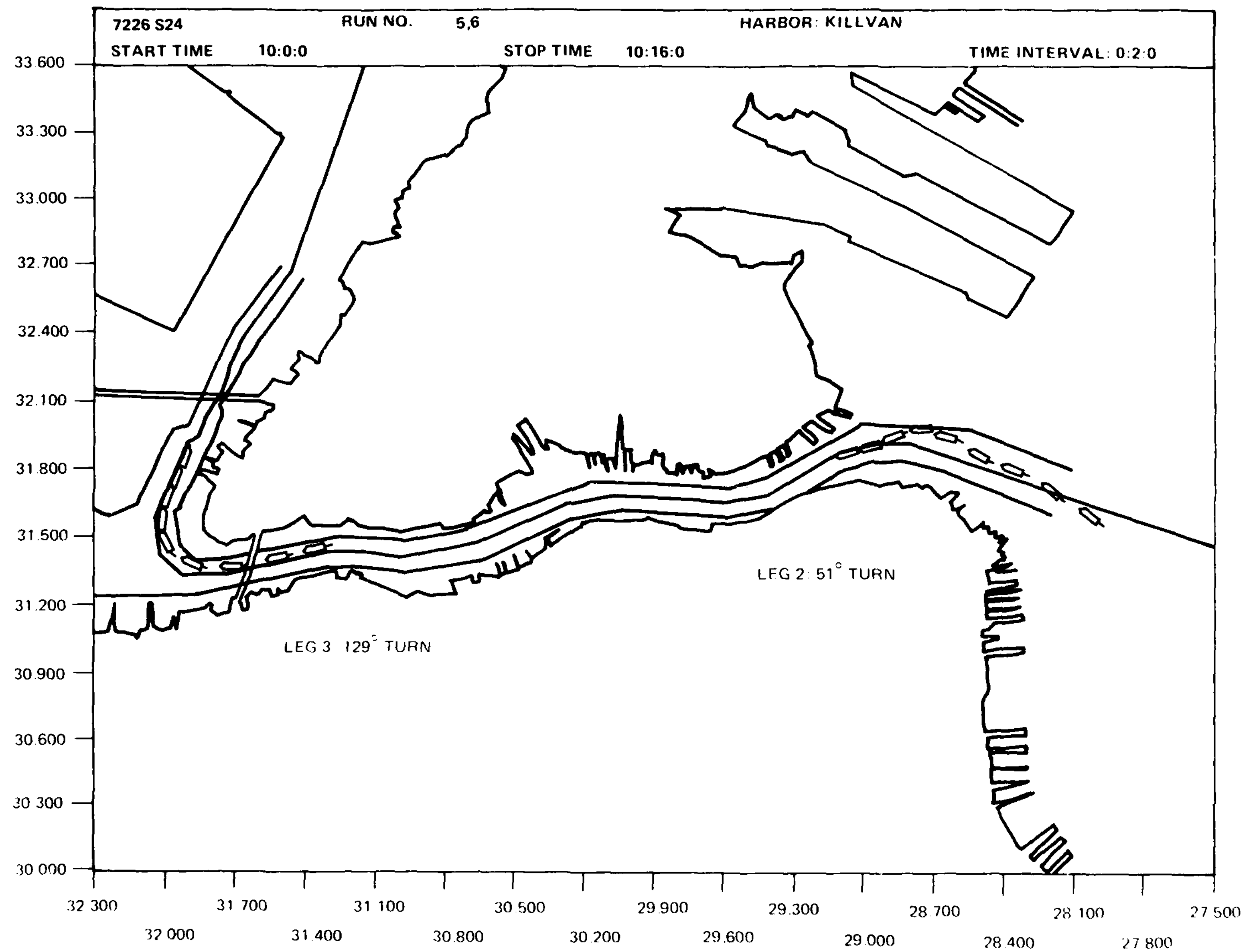

Figure C-10. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

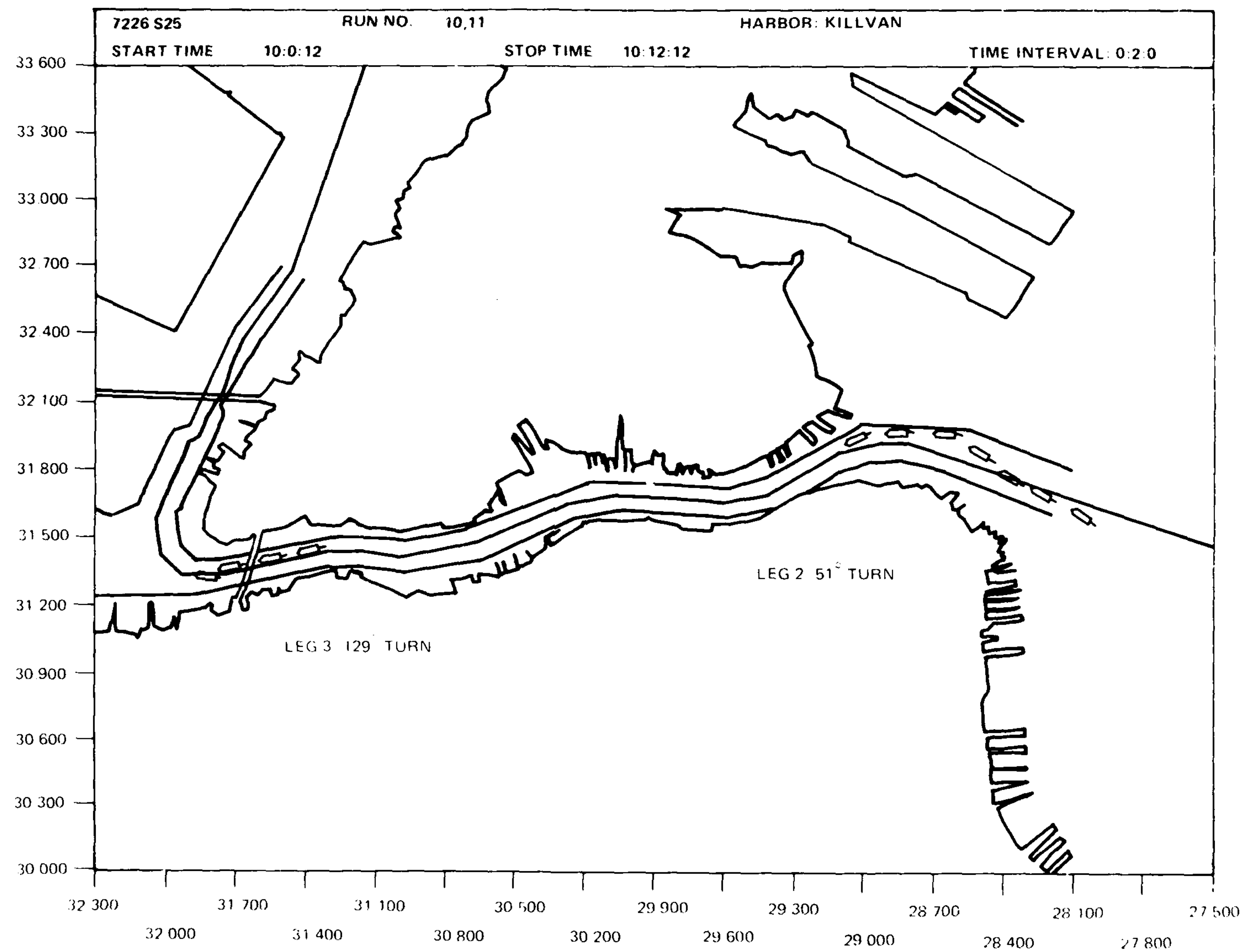

Figure C-11. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

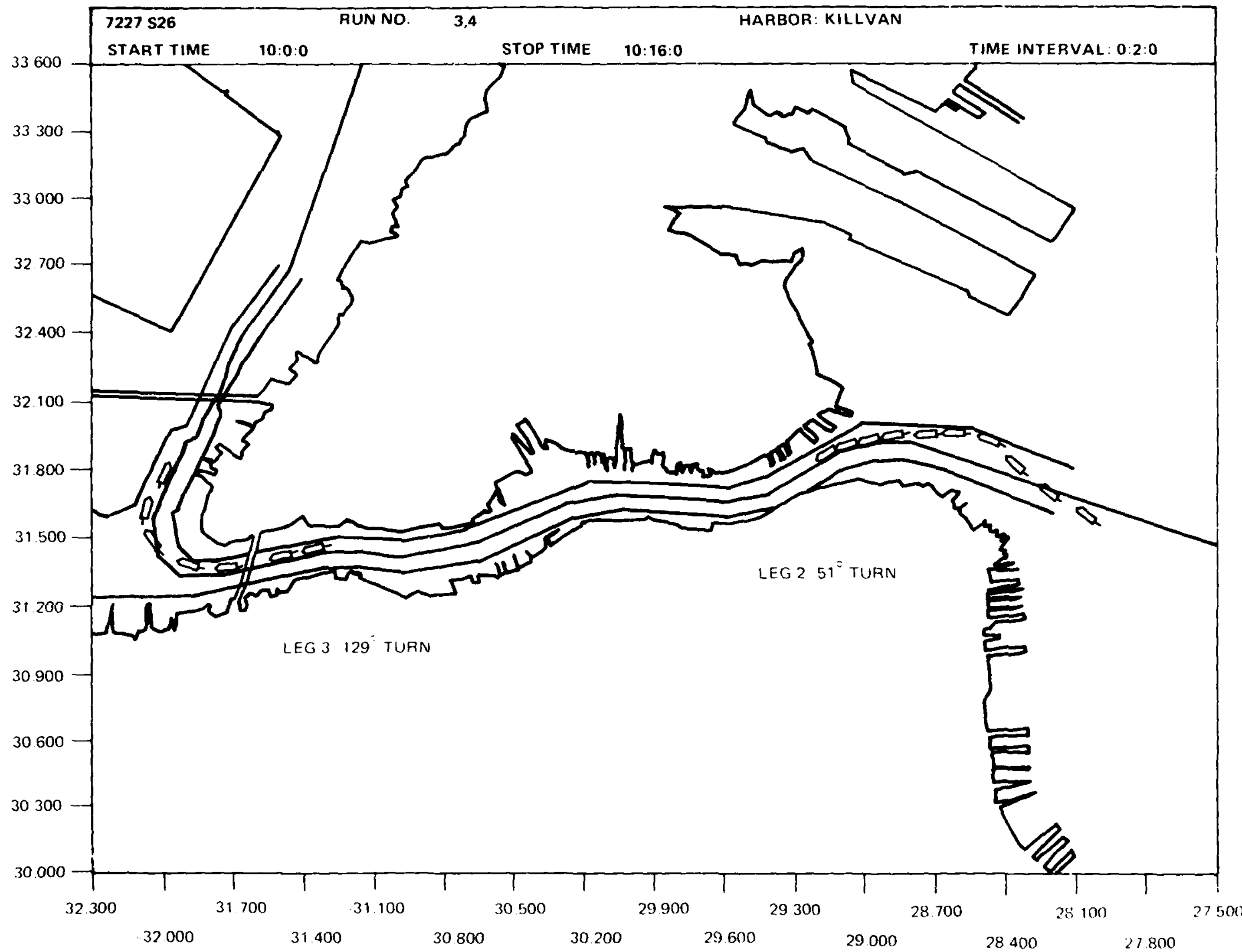

Figure C-12. Track Plots, Masters, Leg 2, 51° Turn and Leg 3, 129° Turn

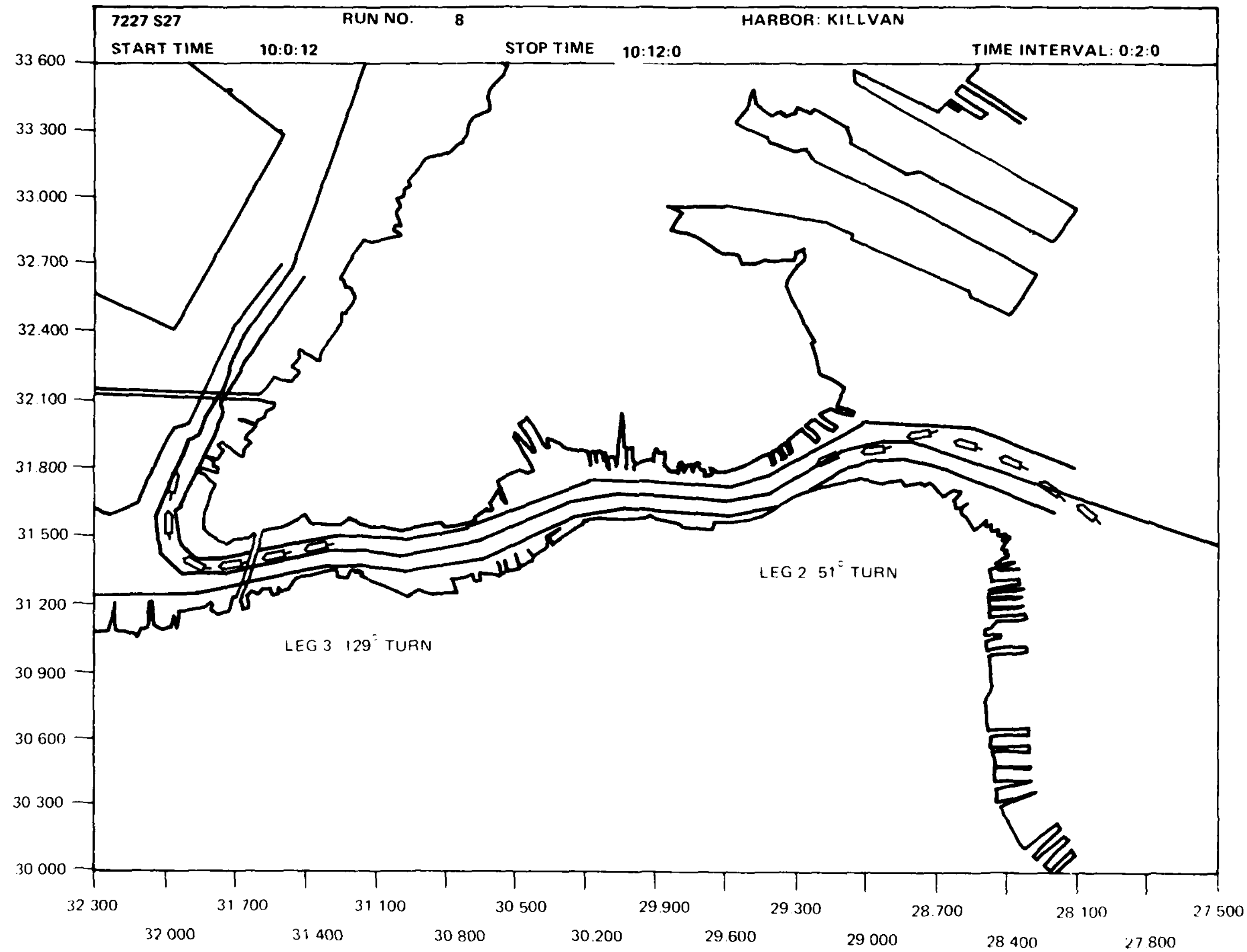

Figure C-13. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

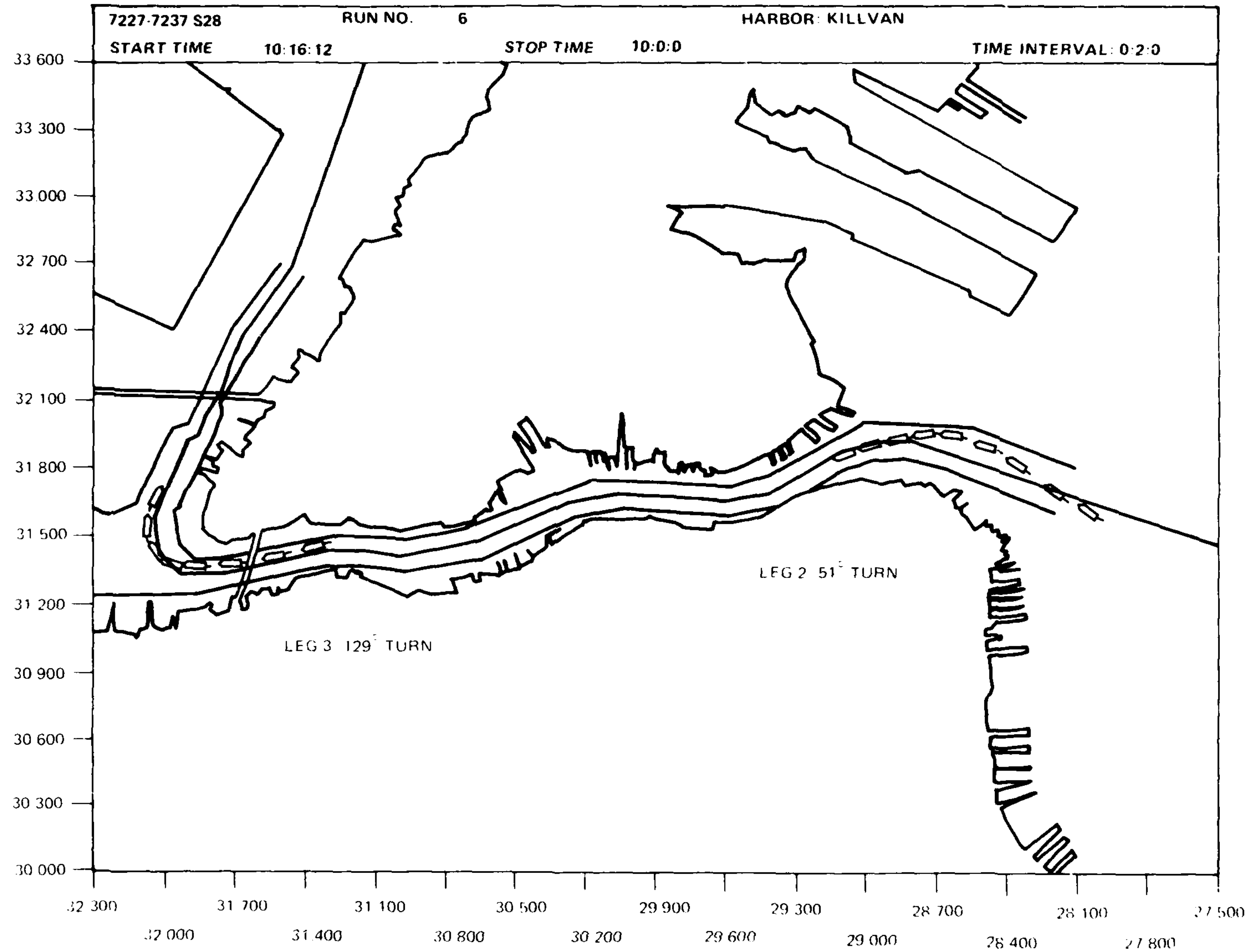

Figure C-14. Track Plots, Masters, Leg 2, 51 Turn and Leg 3, 129 Turn

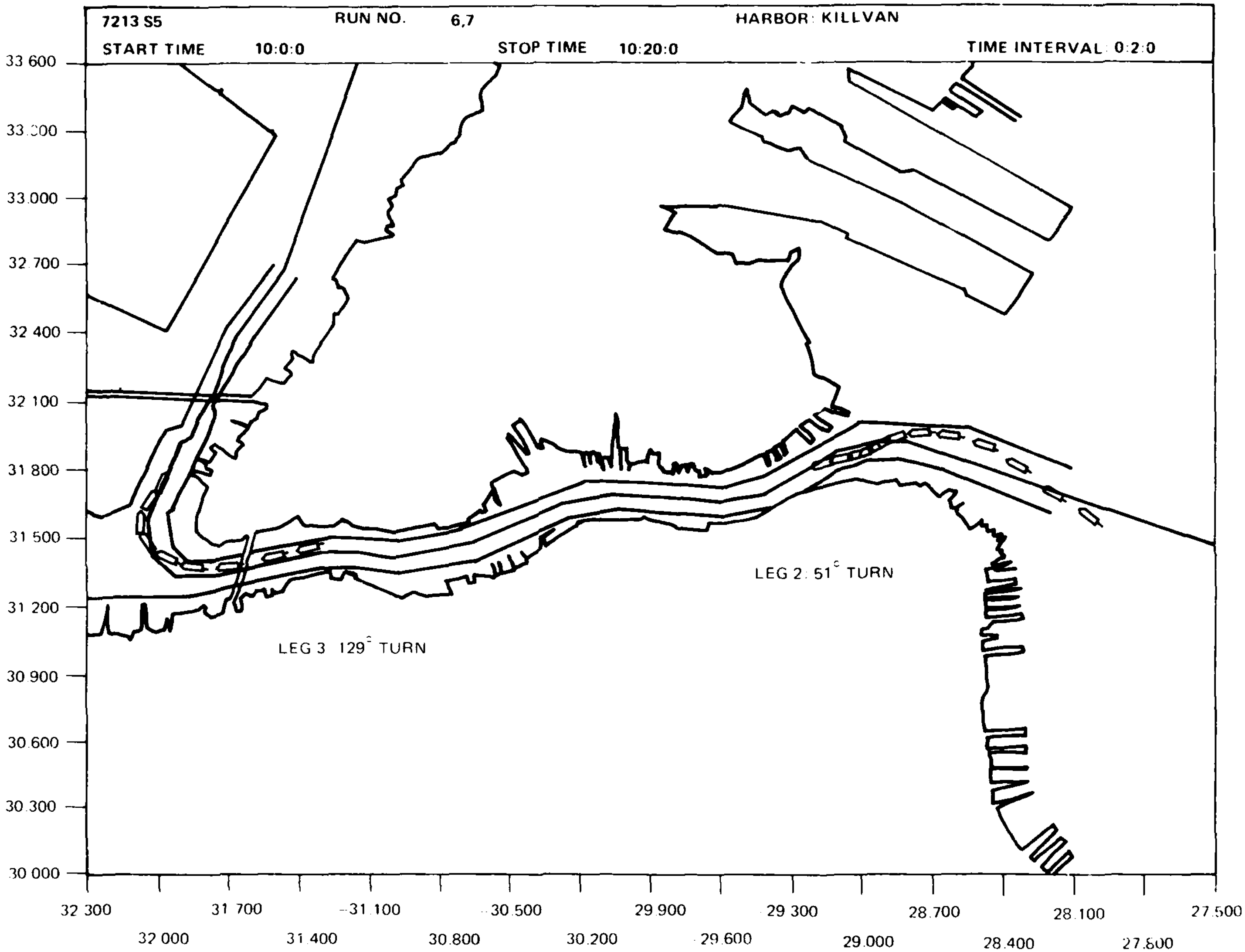

Figure C-15. Track Plots, Pilots, Leg 2, 51° Turn and Leg 3, 129° Turn

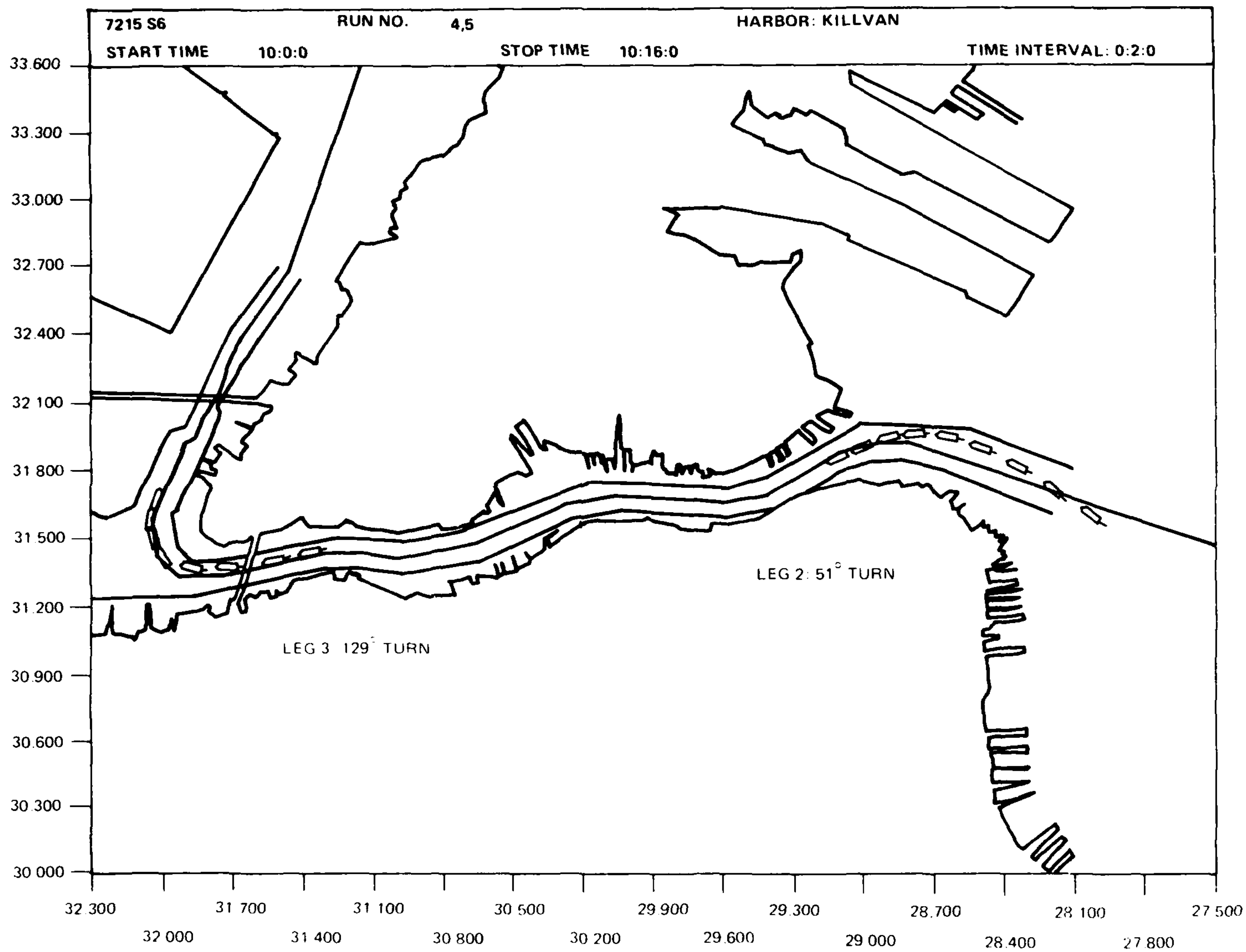

Figure C-16. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

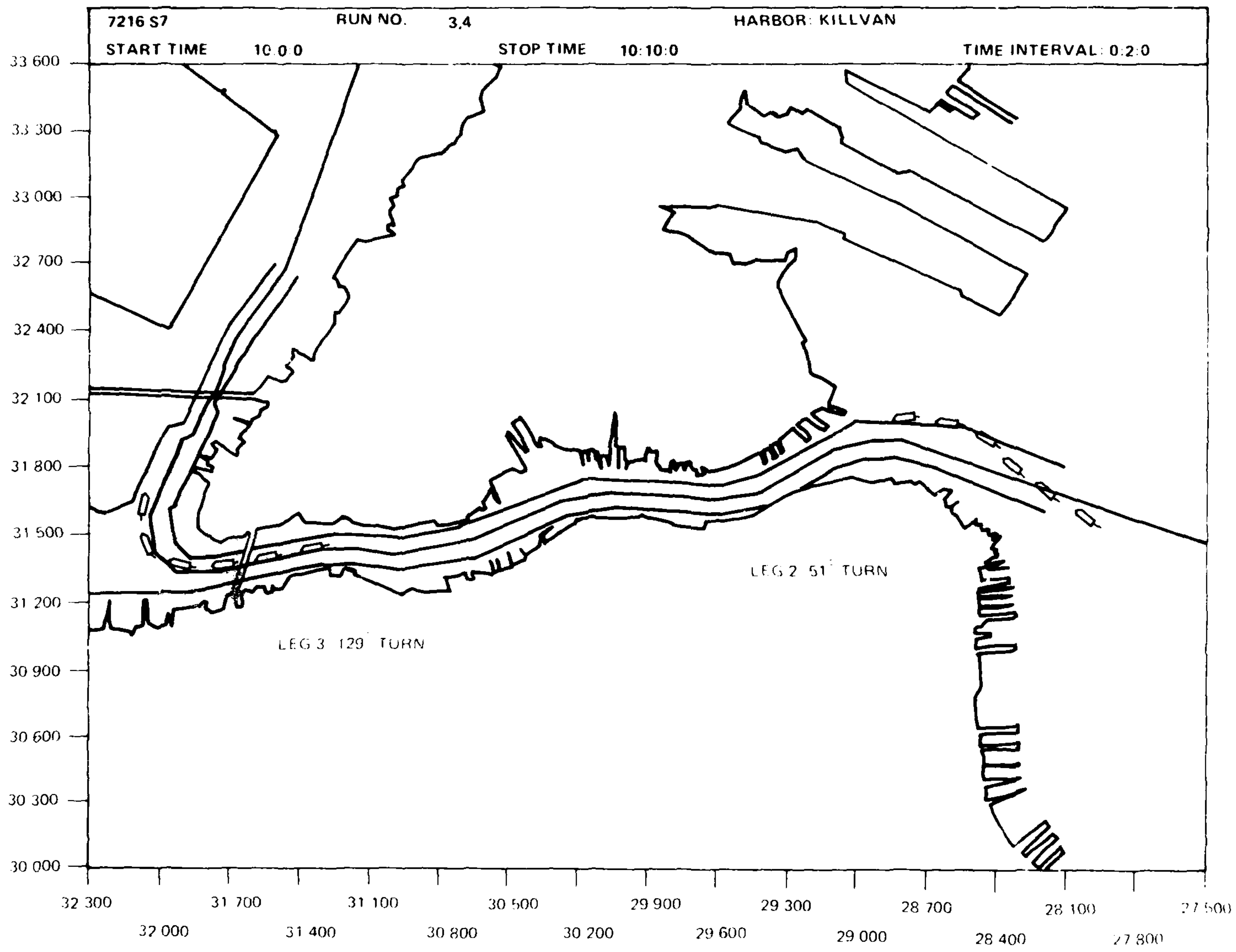

Figure C-17. Track Plots, Pilots, Leg 2, 51° Turn and Leg 3, 129° Turn

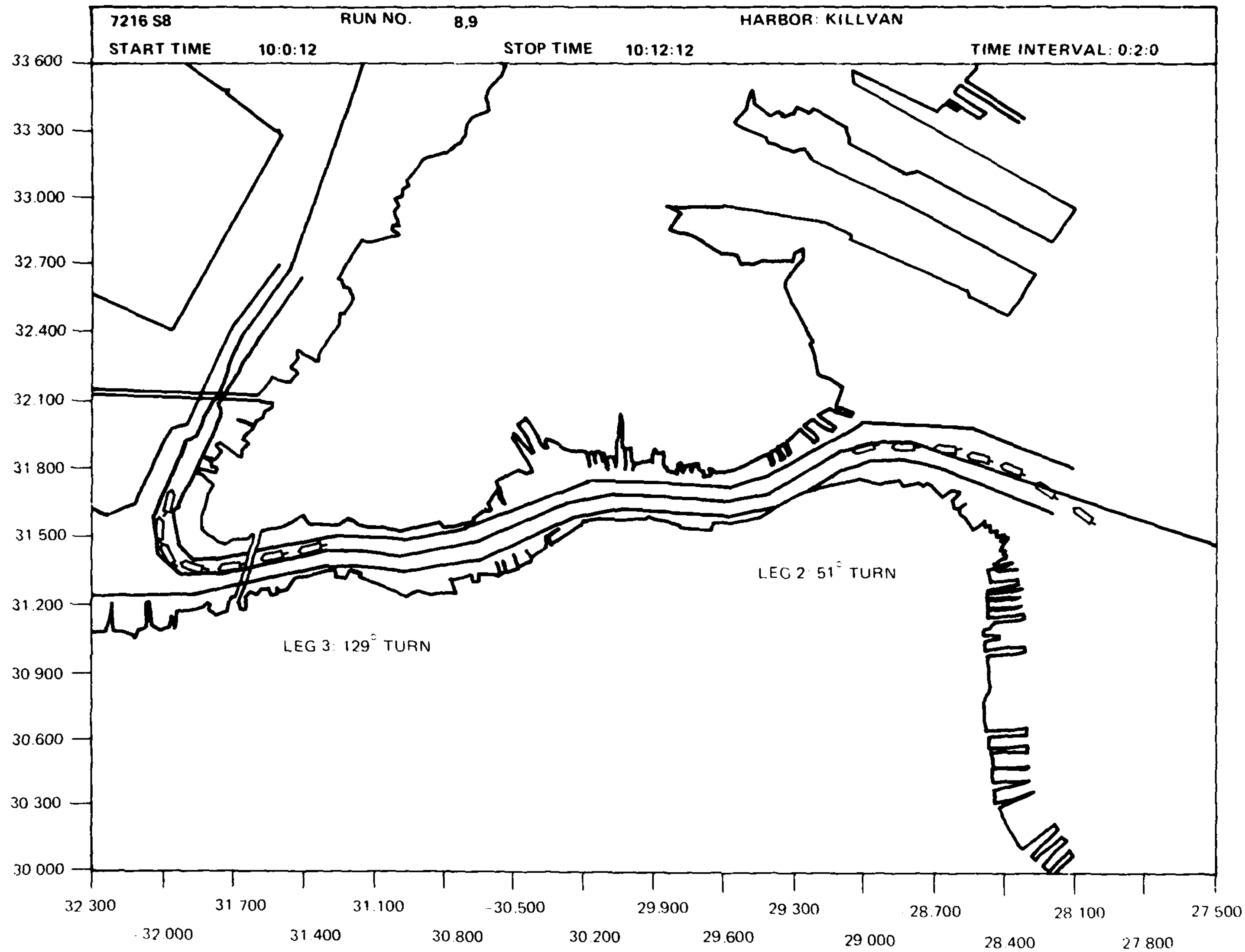

Figure C-18. Track Plots, Pilots, Leg 2, 51° Turn and Leg 3, 129° Turn

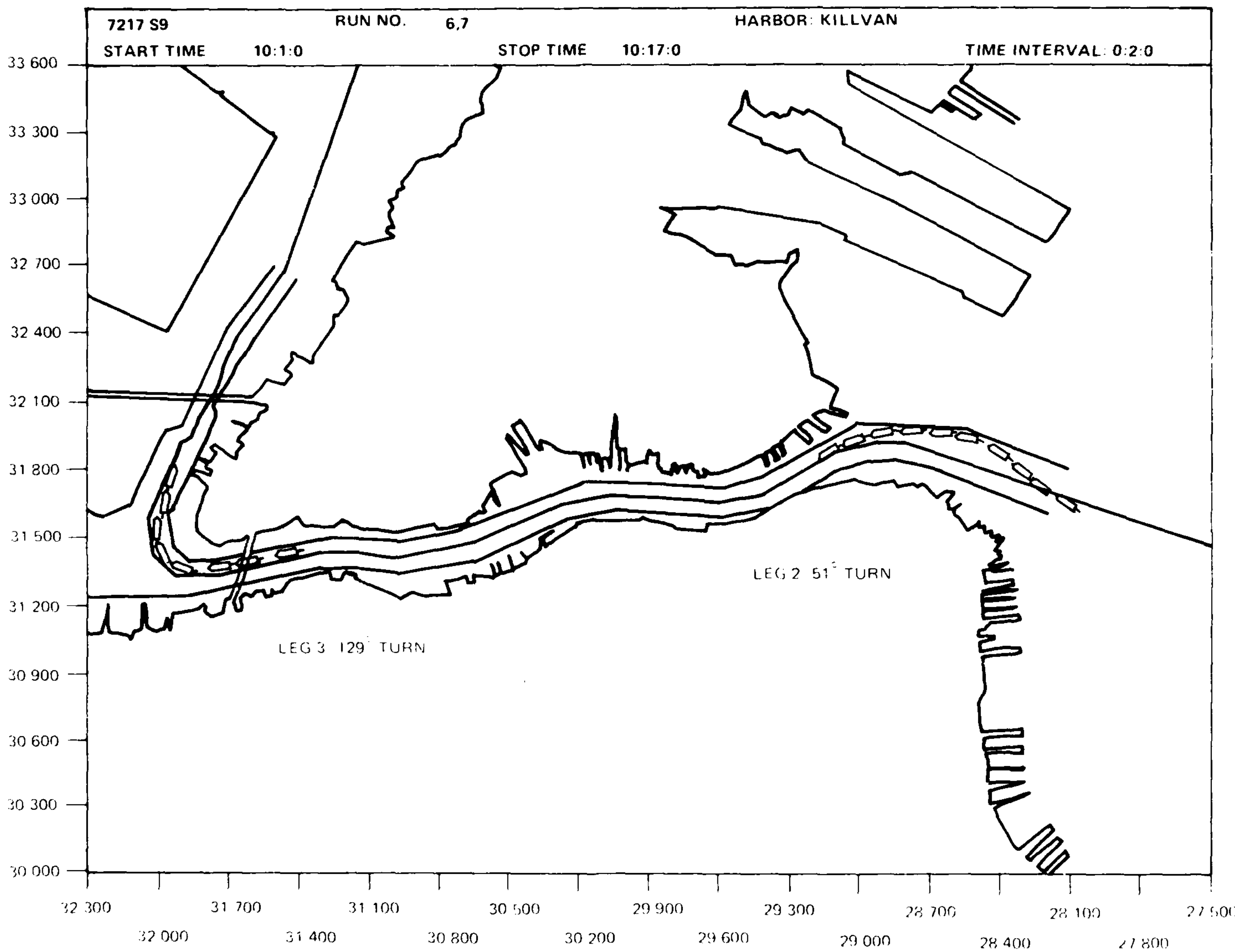

Figure C-19. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

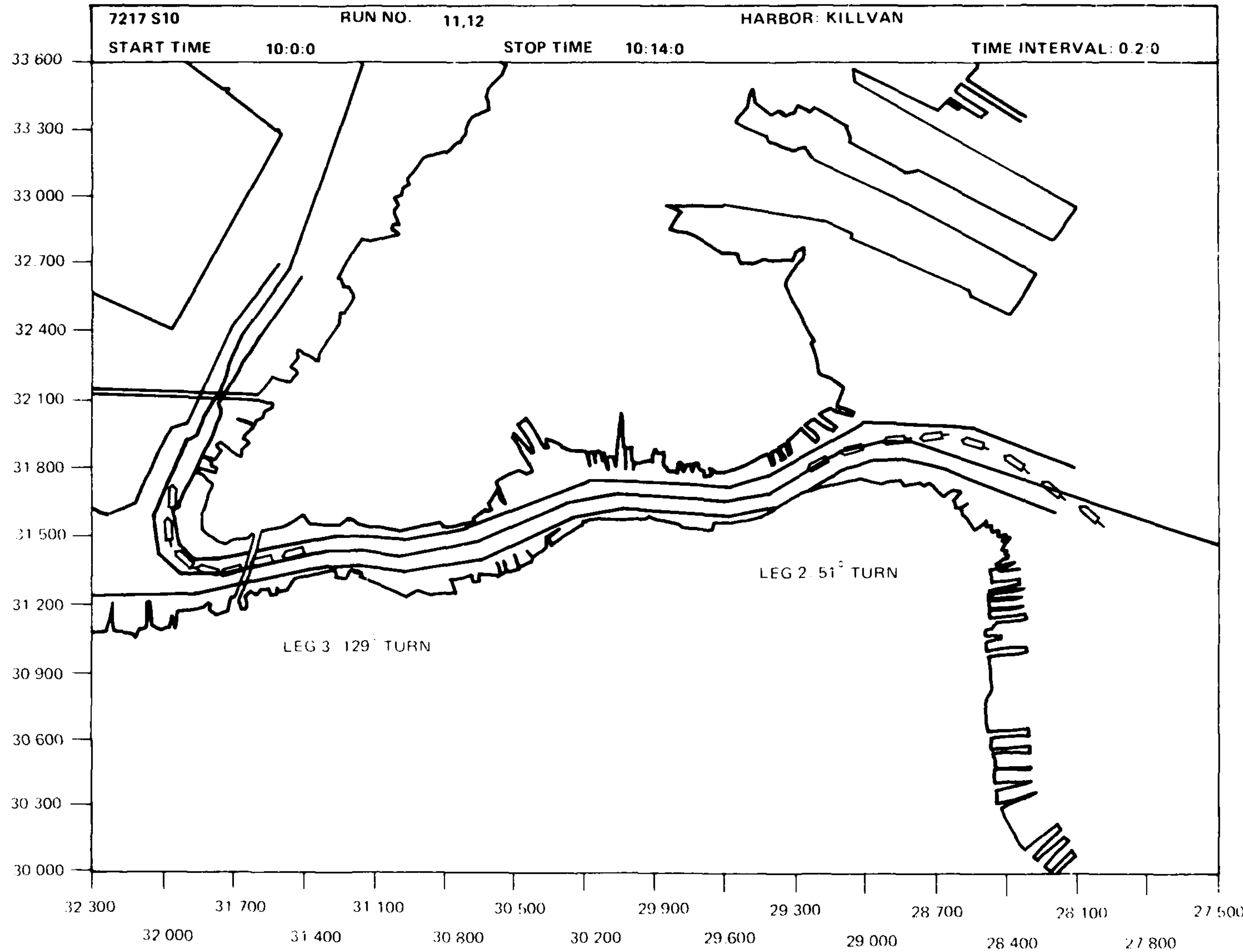

Figure C-20. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

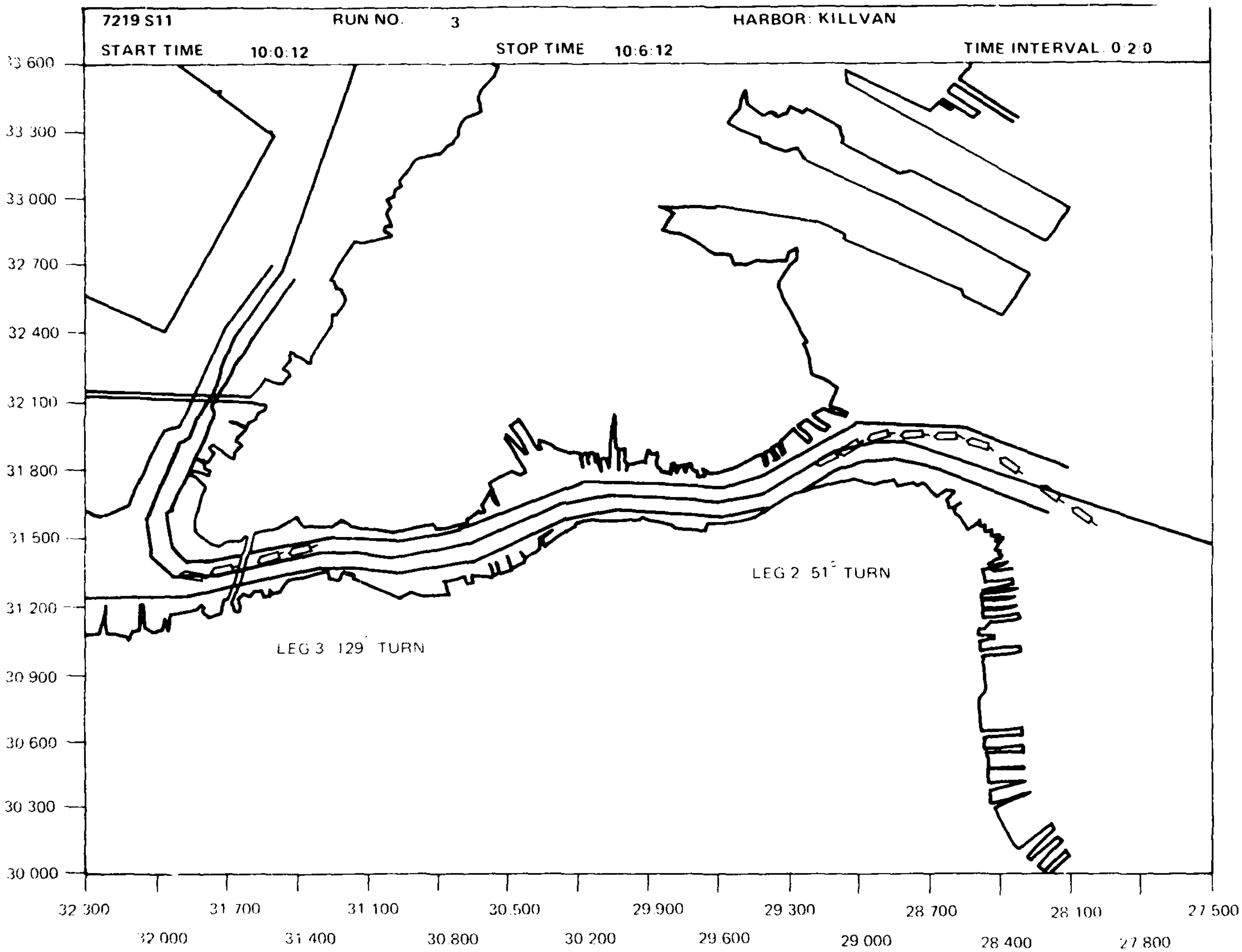

Figure C-21. Track Plots, Pilots, Leg 2, 51° Turn and Leg 3, 129° Turn

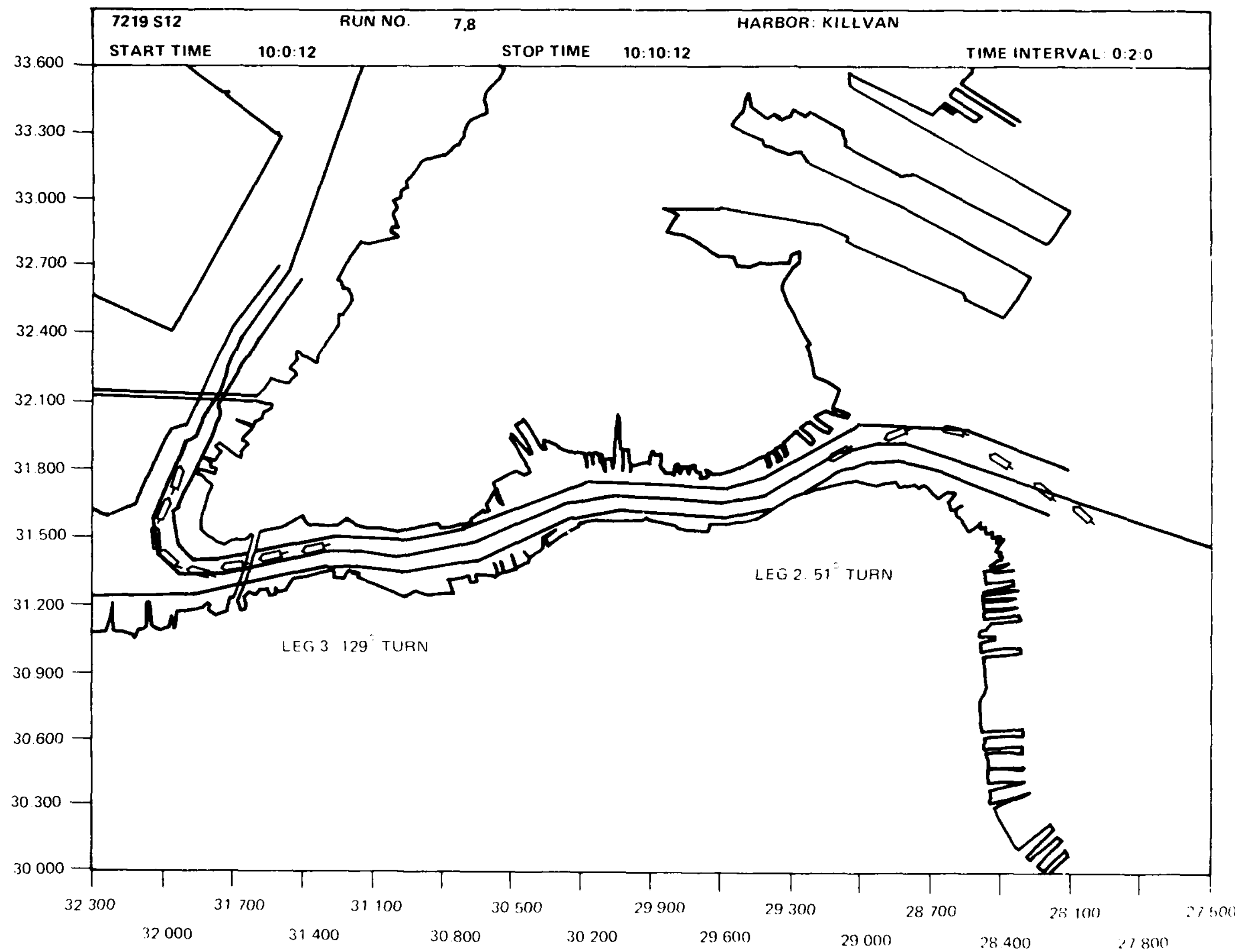

Figure C-22. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

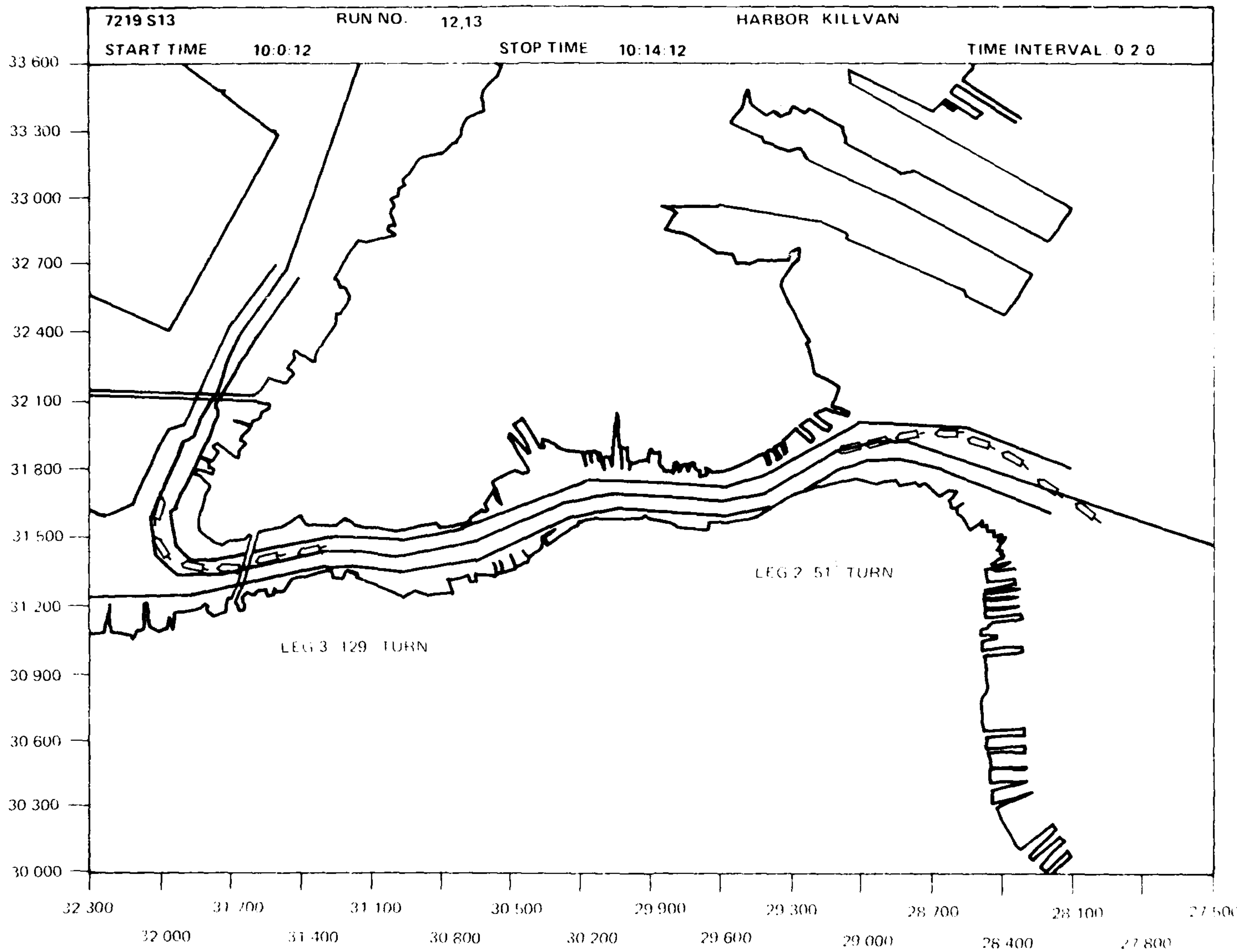

Figure C 23. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

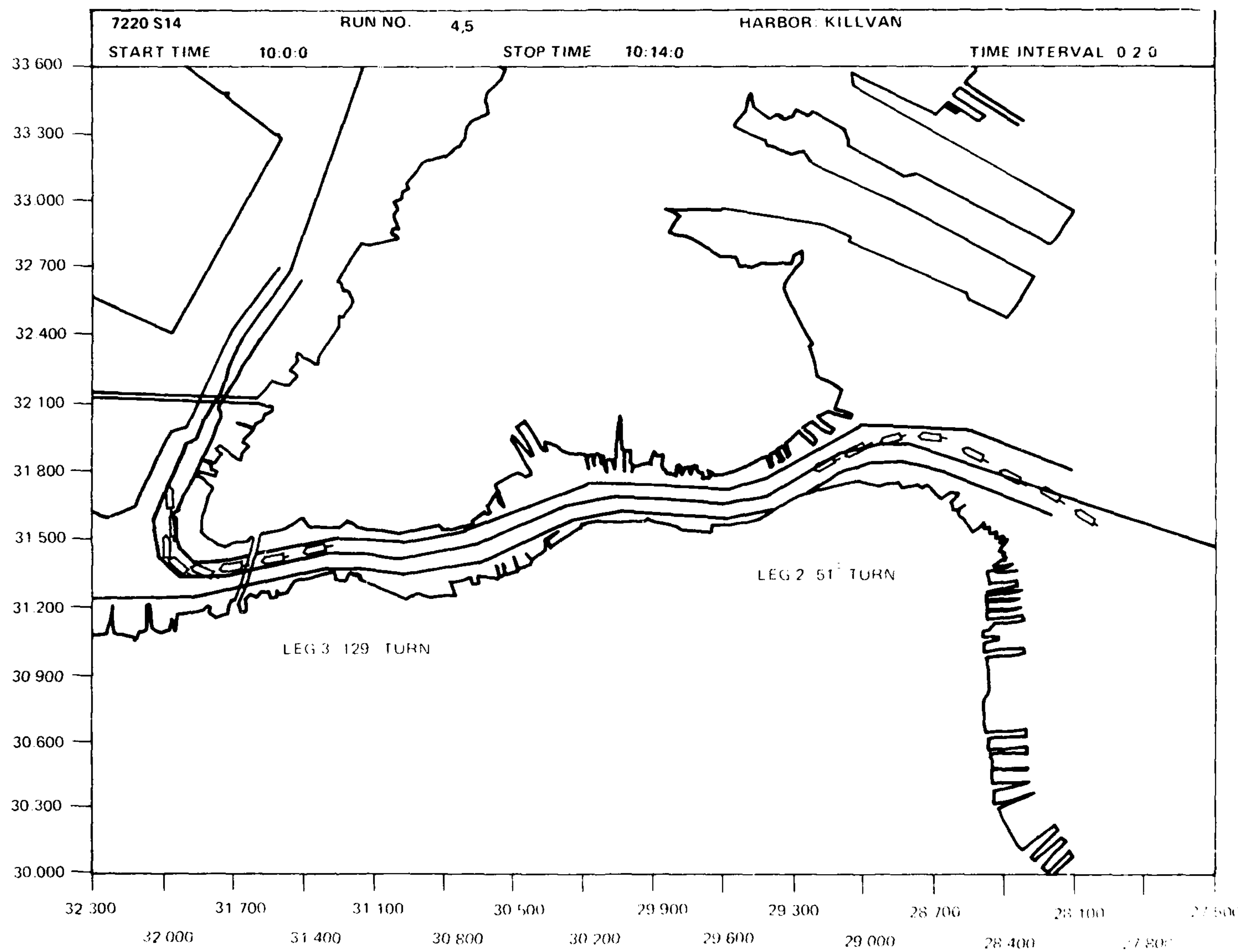

Figure C-24. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

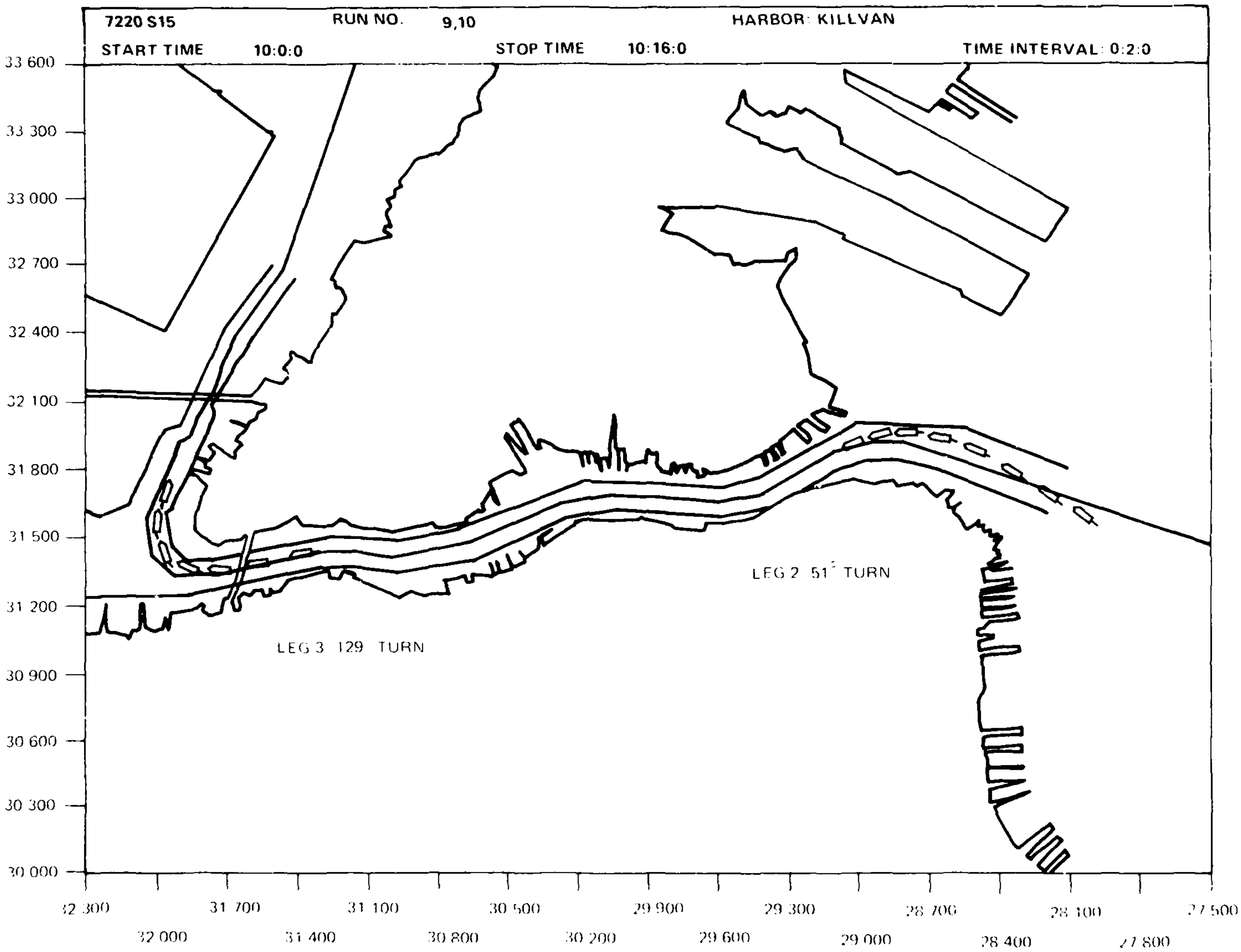

Figure C-25. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

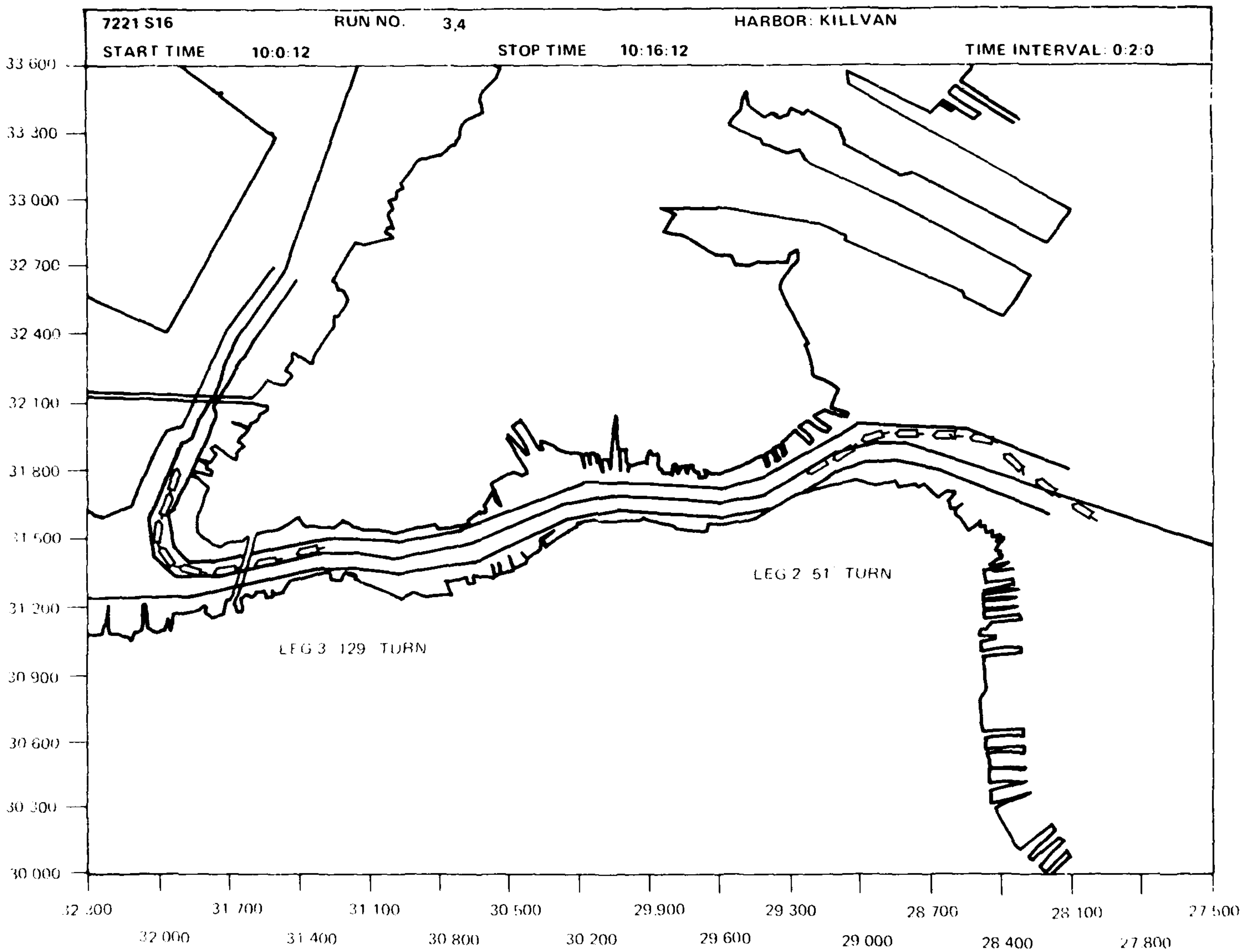

Figure C-26. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

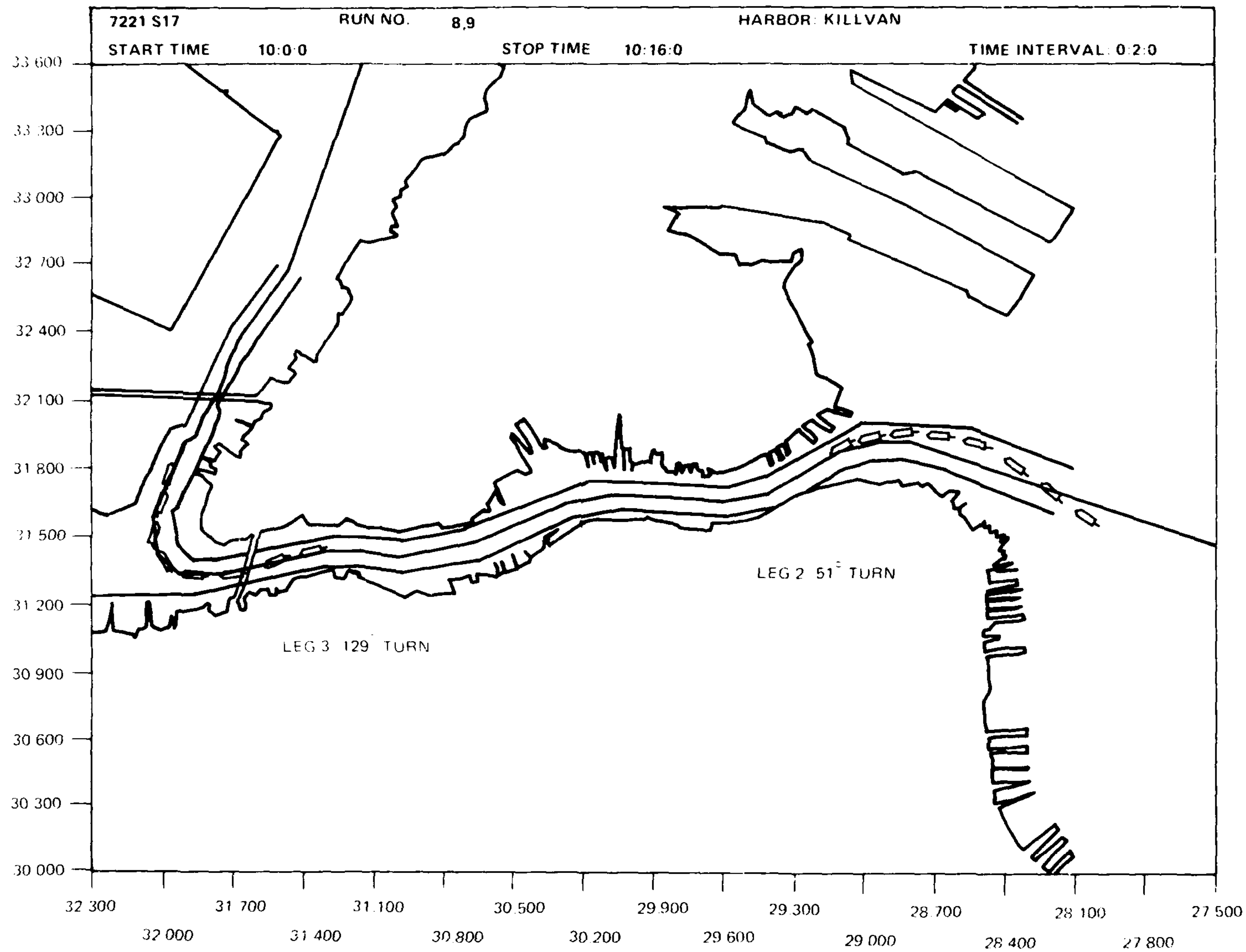

Figure C-27. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

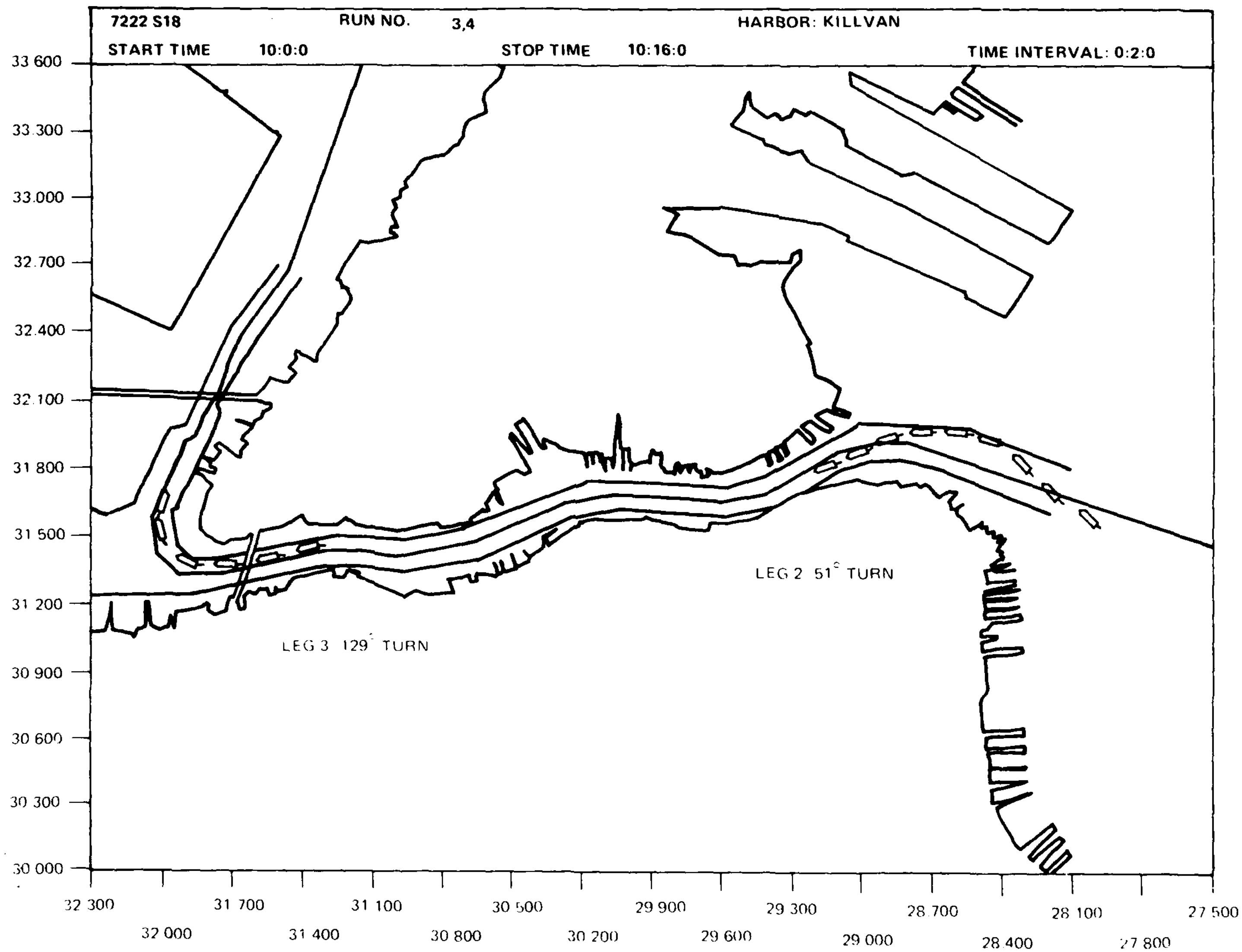

Figure C-28. Track Plots, Pilots, Leg 2, 51 Turn and Leg 3, 129 Turn

TRAINING OBJECTIVE: 51° Turn

PERFORMANCE MEASURE: CPA (in feet) to Ship 3

	Masters	Pilots
$\bar{X}$	487.35	504.55
SD	237.97	154.83
90% Confidence Interval	599.92 to 374.78	577.79 to 431.31

Cutoff Score: > 431.31. Subjects with scores > 431.31 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	10	4
Masters	8	6

χ^2 = 0.622, not significant

χ^2 (with Yates Correction) = 0.156, not significant

Figure C-29. Summary of Data and Contingency Table, CPA (in feet) to Ship 3, Leg 2, 51° Turn

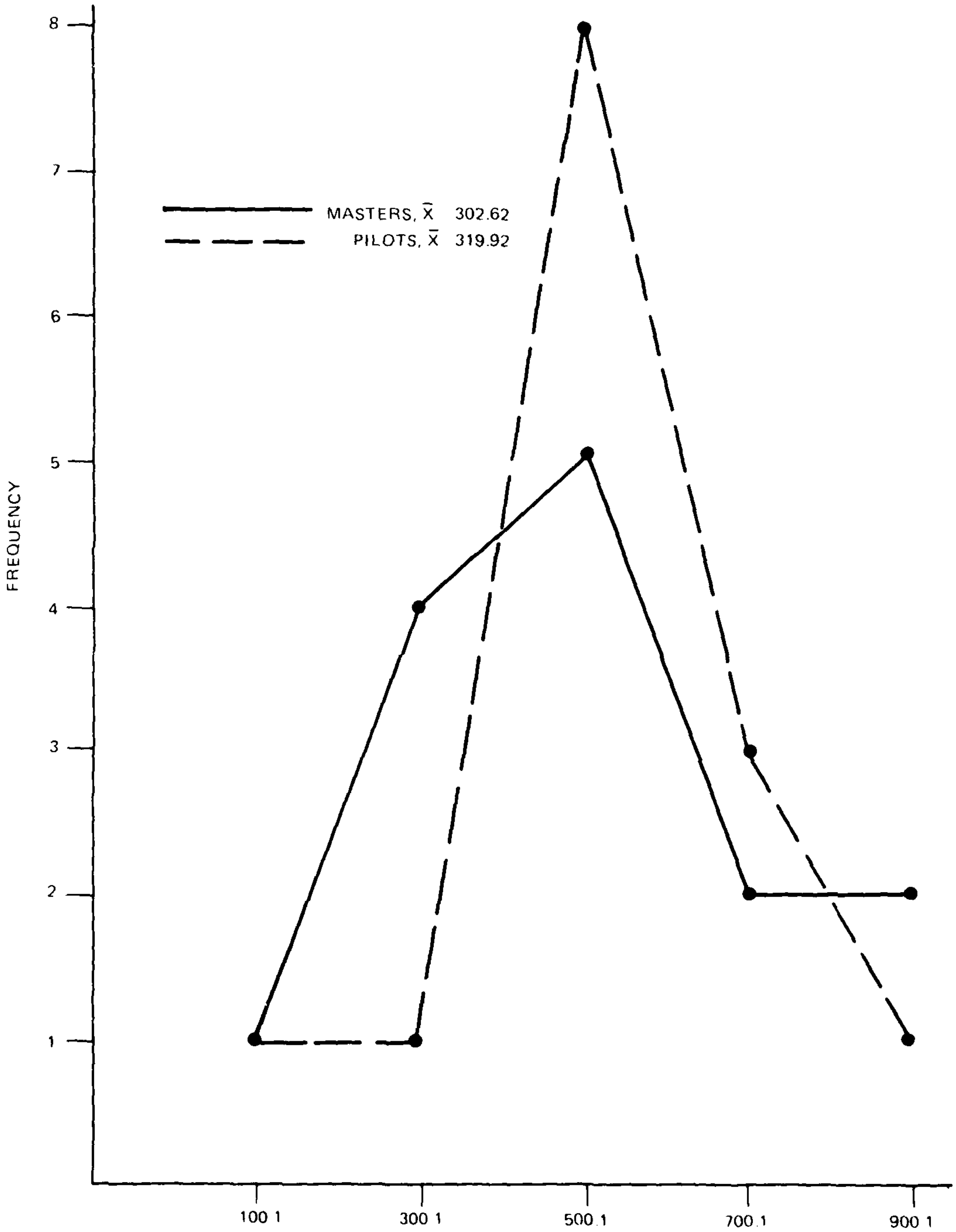

Figure C-30. Frequency Distribution, CPA (in feet) to Ship 3, Leg 2, 51 Turn

TRAINING OBJECTIVE: 51 Turn

PERFORMANCE MEASURE: Maximum Swept Path (in feet)

	Masters	Pilots
X	537.78	548.07
SD	69.50	68.90
90% Confidence Interval	570.65 to 504.91	580.65 to 515.48

Cutoff Score: > 580.65. Subjects with scores > 580.65 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	7	7

χ^2 2.49, *not significant*

Figure C-31. Summary of Data and Contingency Table, Maximum Swept Path (in feet), Leg 2, 51 Turn

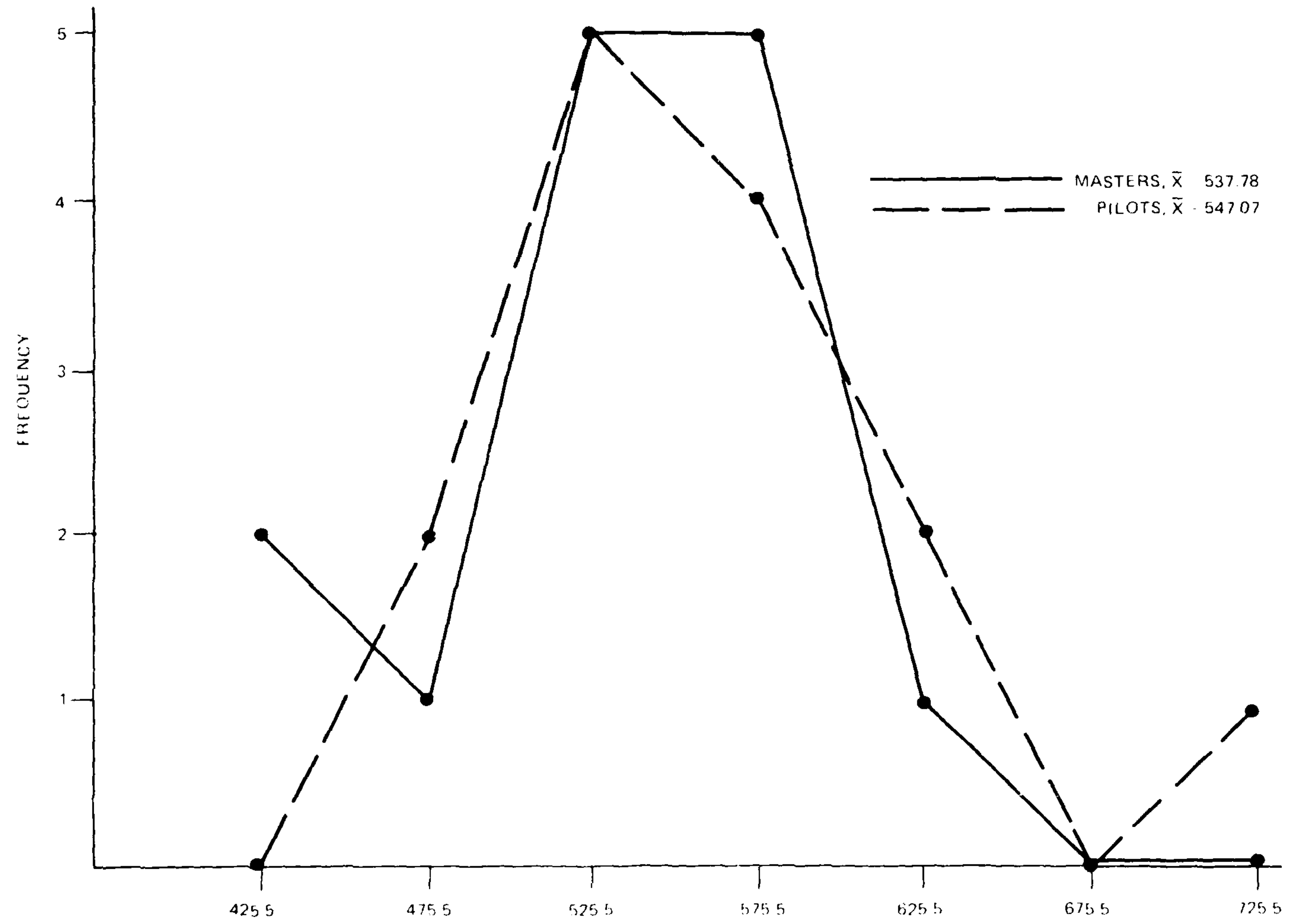

Figure C-32. Frequency Distribution, Maximum Swept Path (in feet), Leg 2, 51 Turn

TRAINING OBJECTIVE: 51 Turn

PERFORMANCE MEASURE: Average Swept Path (in feet)

	Masters	Pilots
X	302.62	319.92
SD	38.88	36.92
90% Confidence Interval	321.01 to 284.23	337.38 to 302.45

Cutoff Score: > 337.38. Subjects with scores > 377.38 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	12	2
Masters	12	2

χ^2 (with Yates Correction) = 0.292, not significant

Figure C-33. Summary of Data and Contingency Table, Average Swept Path (in feet), Leg 2, 51 Turn

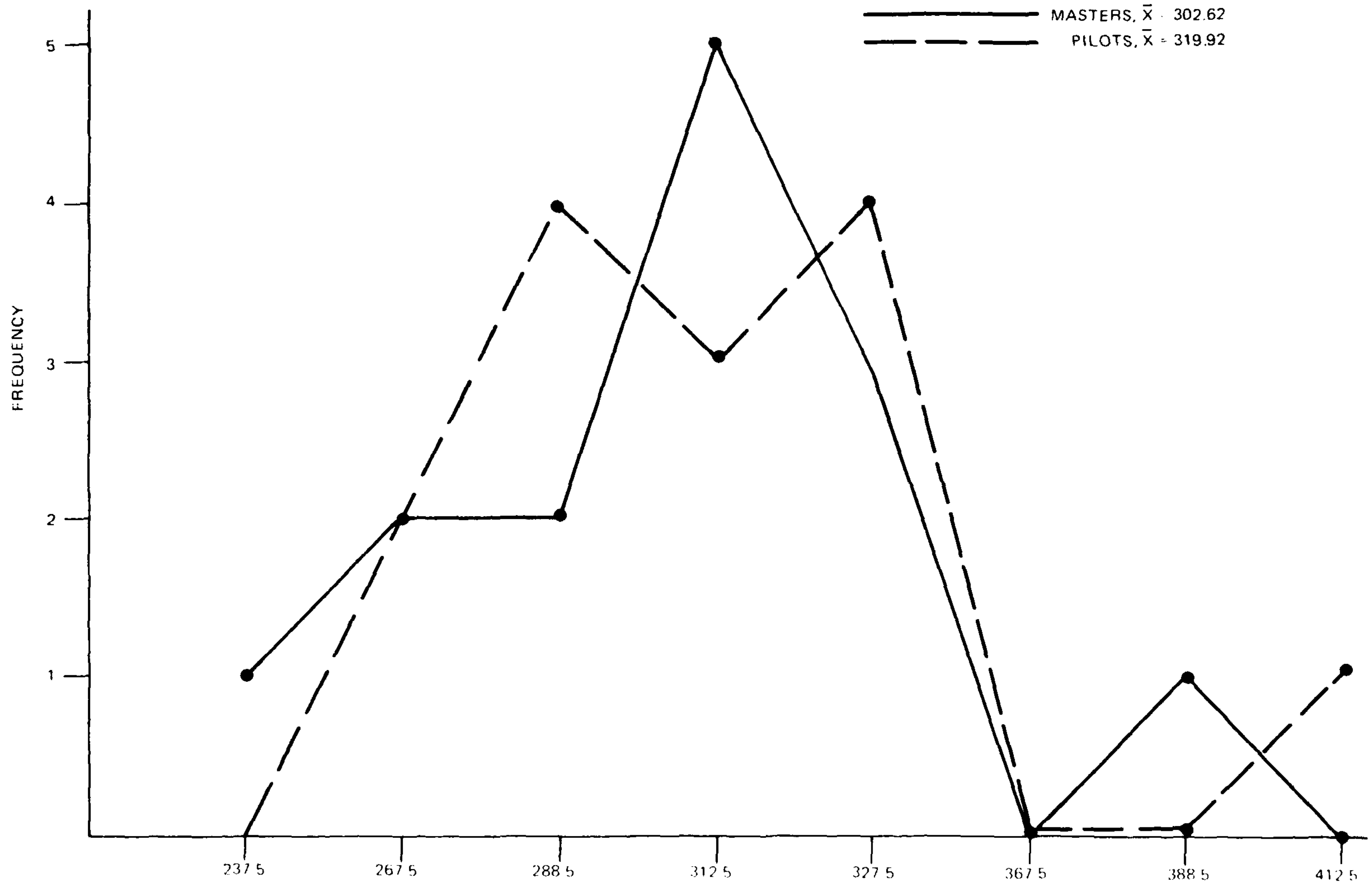

Figure C-34. Frequency Distribution Average Swept Path, Leg 2, 51 Turn

TRAINING OBJECTIVE: 51 Turn

PERFORMANCE MEASURE: Maximum Ratio Swept Path

	Masters	Pilots
$\bar{X}$	.50470	.54806
SD	.1051	.0813
90% Confidence Interval	.55442	.58652 to .50960

Cutoff Score: > 0.58652. Subjects with scores > 0.58652 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	13	1

χ^2 = (with Yates Correction) = 0.291, not significant

Figure C-35. Summary of Data and Contingency Table, Maximum Ratio Swept Path, Leg 2, 51 Turn

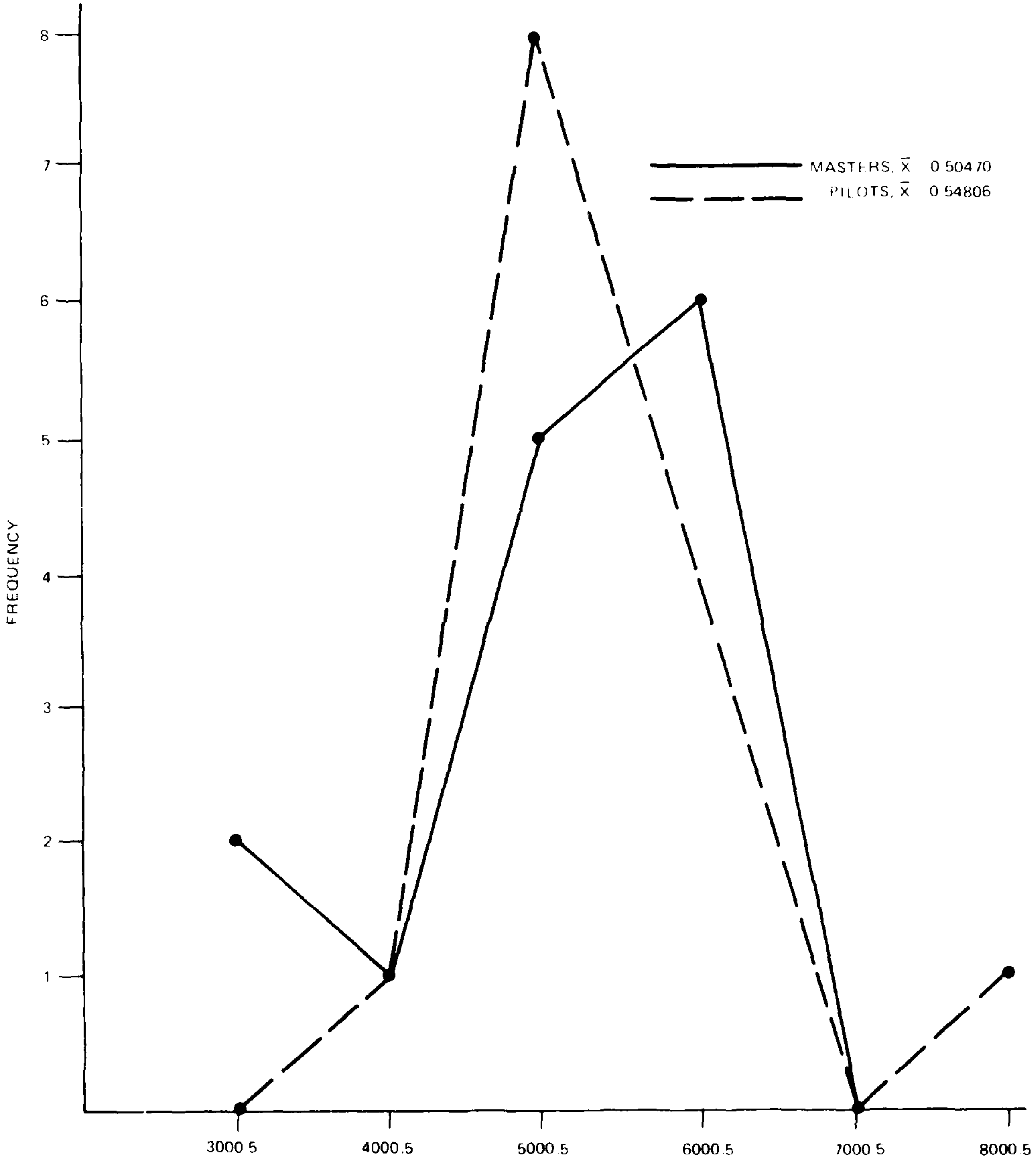

Figure C-36. Frequency Distribution, Maximum Ratio Swept Path, Leg 2, 51 Turn

TRAINING OBJECTIVE: 51 Turn

PERFORMANCE MEASURE: Average Ratio Path

	Masters	Pilots
X	0.25369	.26964
SD	0.0312	.0359
90% Confidence Interval	0.26845 to 0.23893	.28662 to 0.25265

Cutoff Score $\geq$ 0.28662. Subjects with scores $>$ 0.28662 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	11	3
Masters	12	2

χ^2 = (with Yates Correction) = 0, not significant

Figure C-37. Summary of Data and Contingency Table, Average Ratio Swept Path, Leg 2, 51 Turn

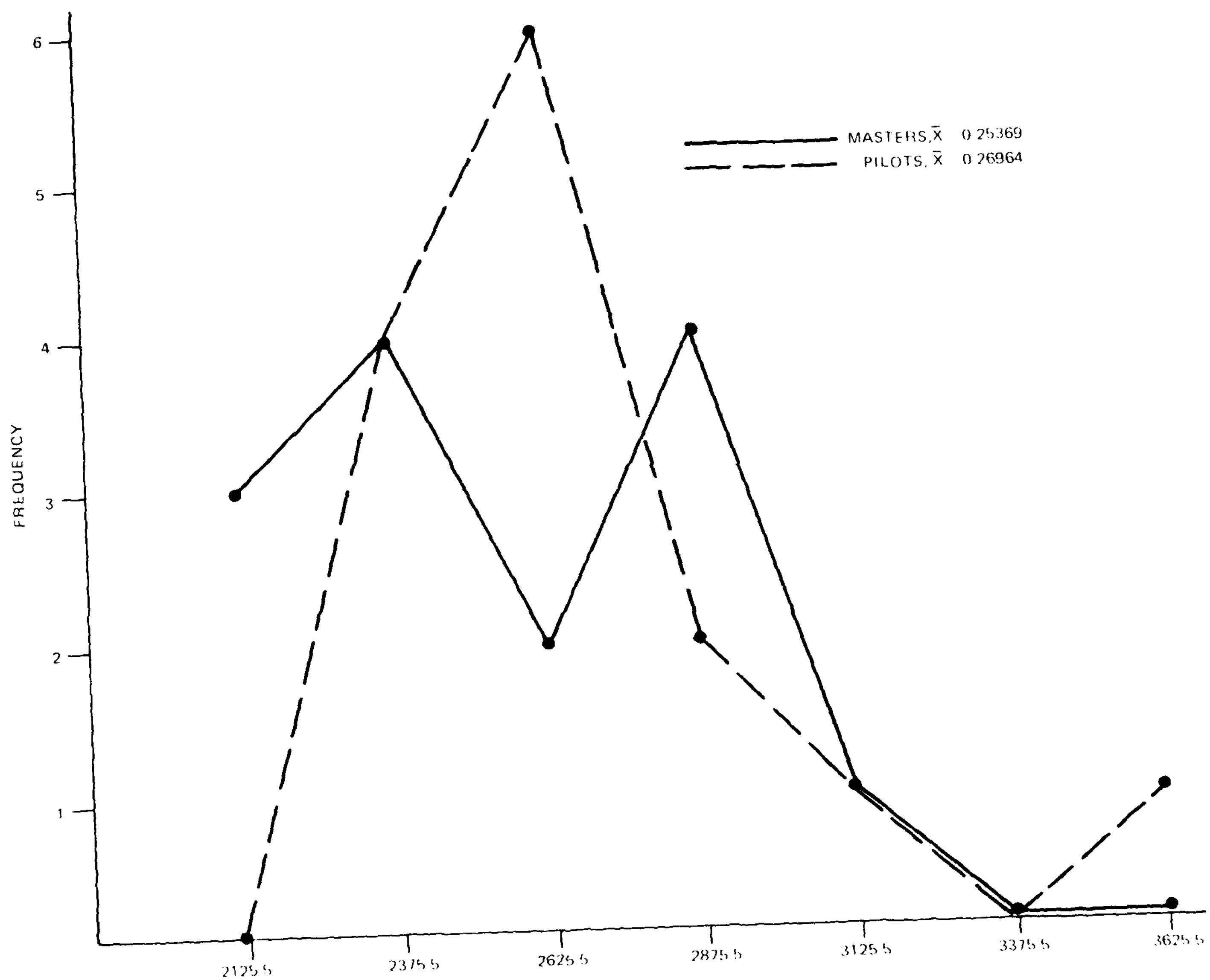

Figure C-38. Frequency Distribution, Average Ratio Swept Path, Leg 2, 51 Turn

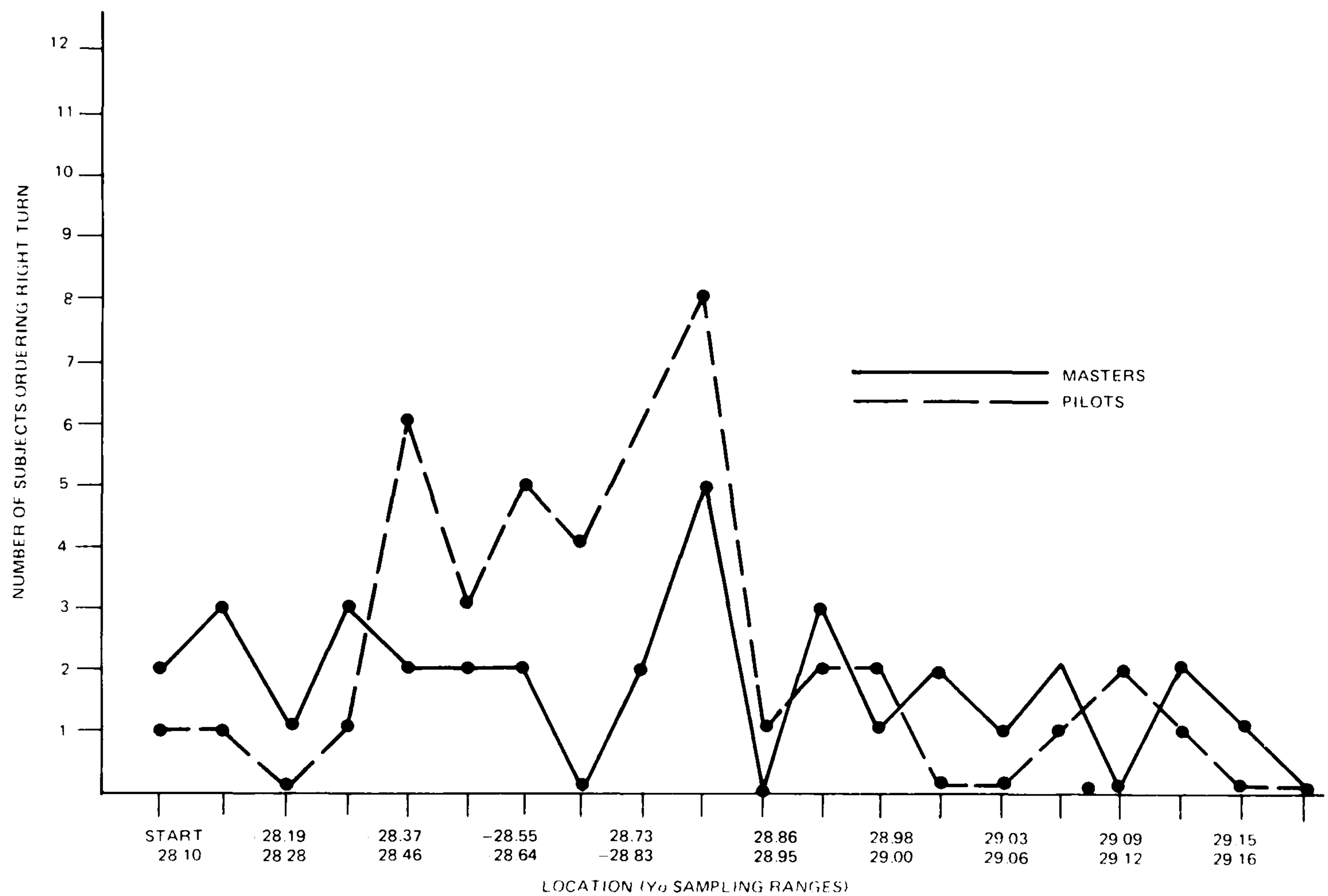

Figure C-39. Right Rudder Commands by Location, Leg 2, 51 Turn

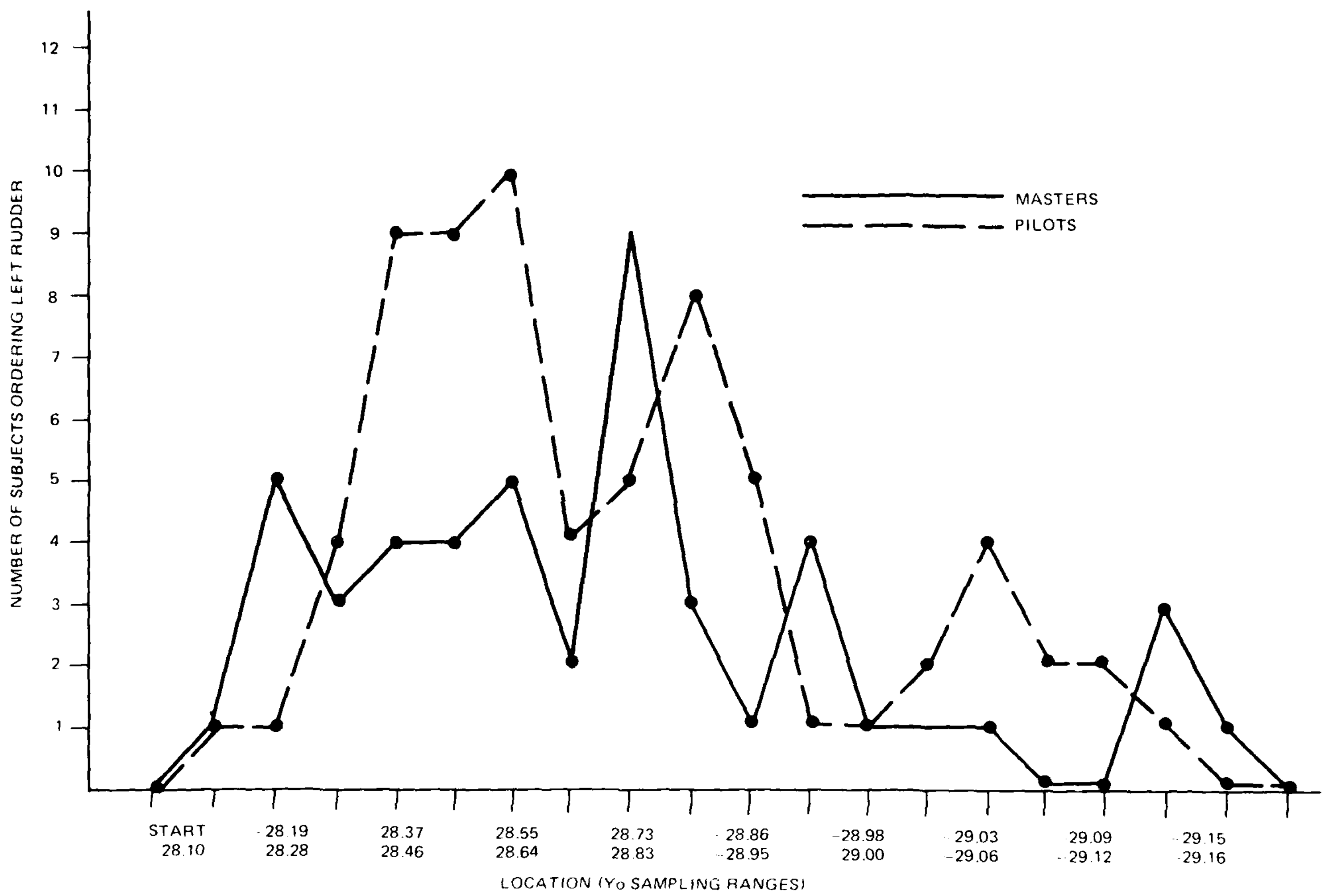

Figure C-40. Midship Rudder Commands by Location, Leg 2, 51° Turn

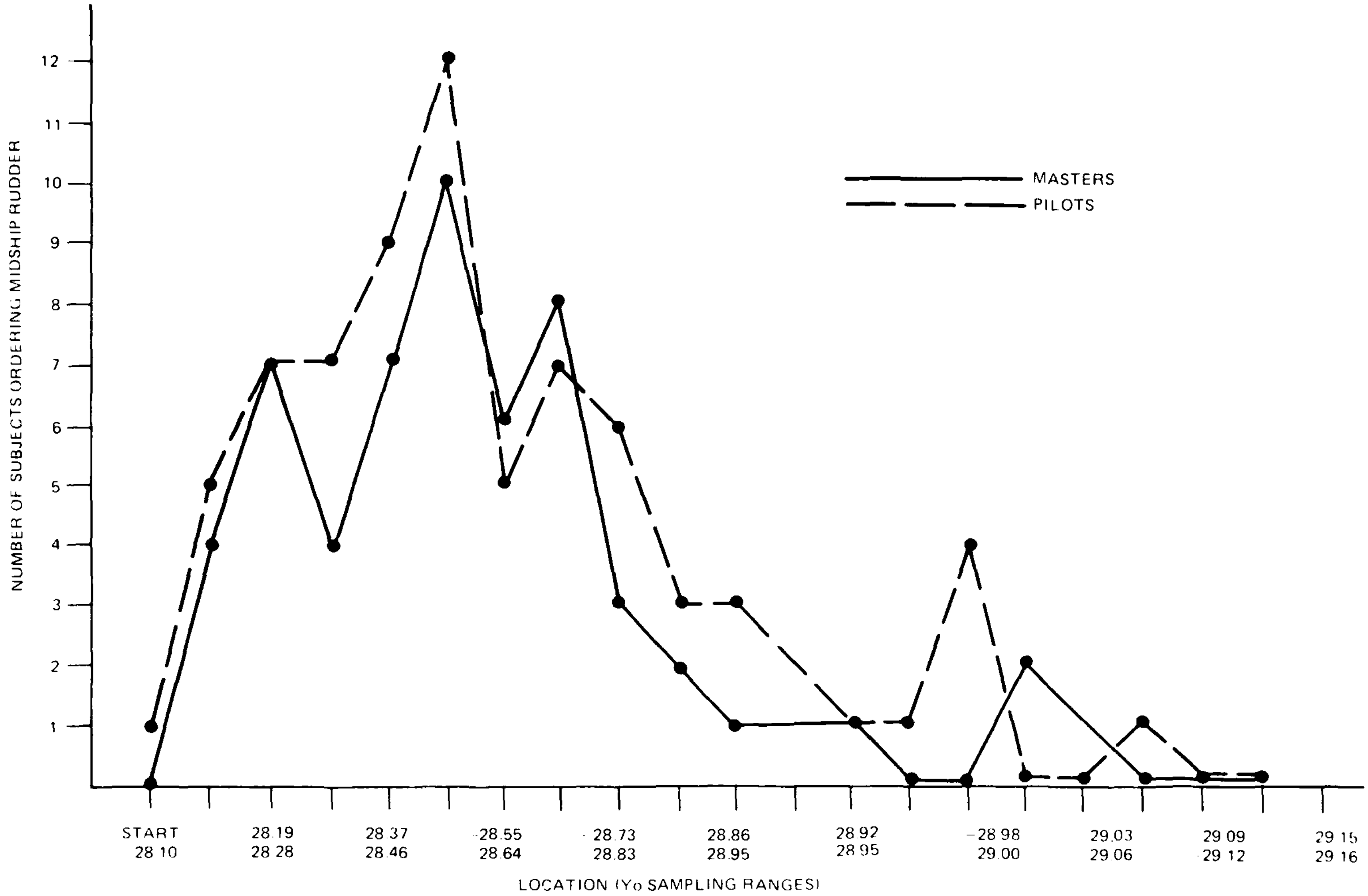

Figure C-41. Left Rudder Commands by Location, Leg 2, 51° Turn

		Rudder	RPM Ahead	RPM Astern	Thruster
	$\bar{x}$	67.14	35.14	18	8.84
Masters	S.D.	4.62	18.03	–	11.08
	n	14	14	1	2
	$\bar{x}$	69.64	31.43	18	50
Pilots	S.D.	5.06	21.95	–	–
	n	14	14	2	1
	t*	1.365	0.489	–	–
	df	26	26	–	–

*All comparisons of means for Masters and Pilots are not significant.

Figure C-42. Rudder, Engine, Thruster Percent Remaining for Masters and Pilots, Leg 2, 51 Turn

APPENDIX D

PERFORMANCE MEASURES APPENDICES

LEG 3 – 129° TURN

TRAINING OBJECTIVE: NEGOTIATING A 129° TURN AROUND SHOAL WITH ONCOMING TRAFFIC

LIST OF ILLUSTRATIONS

Number	
D-1	Summary of Data and Contingency Table, Maximum Swept Path (in feet), Leg 3, 129° Turn
D-2	Frequency Distribution and Confidence Interval, Maximum Swept Path (in feet), Leg 3, 129° Turn
D-3	Summary of Data and Contingency Table, Average Swept Path (in feet), Leg 3, 129° Turn
D-4	Frequency Distribution, Average Swept Path (in feet), Leg 3, 129° Turn
D-5	Summary of Data and Contingency Table, Maximum Ratio Swept Path, Leg 3, 129° Turn
D-6	Frequency Distribution and Confidence Interval, Maximum Ratio Swept Path, Leg 3, 129° Turn
D-7	Summary of Data and Contingency Table, Average Ratio Swept Path, Leg 3, 129° Turn
D-8	Frequency Distribution, Average Ratio Swept Path, Leg 3, 129° Turn
D-9	Percent of Rudder, Engine, and Thruster Remaining, Leg 3, 129° Turn

TRAINING OBJECTIVE: 129 Turn

PERFORMANCE MEASURE: Maximum Swept Path

	Masters	Pilots
X	534.01	513.98
SD	52.70	43.80
90% Confidence Interval	558.93 to 509.09	534.71 to 493.25

Cutoff Score: > 534.71. Subjects with scores > 534.71 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	13	1
Masters	7	7

χ^2 = (with Yates Correction) = 4.38, $p < 0.025$

Figure D-1. Summary of Data and Contingency Table, Maximum Swept Path (in feet), Leg 3, 129 Turn

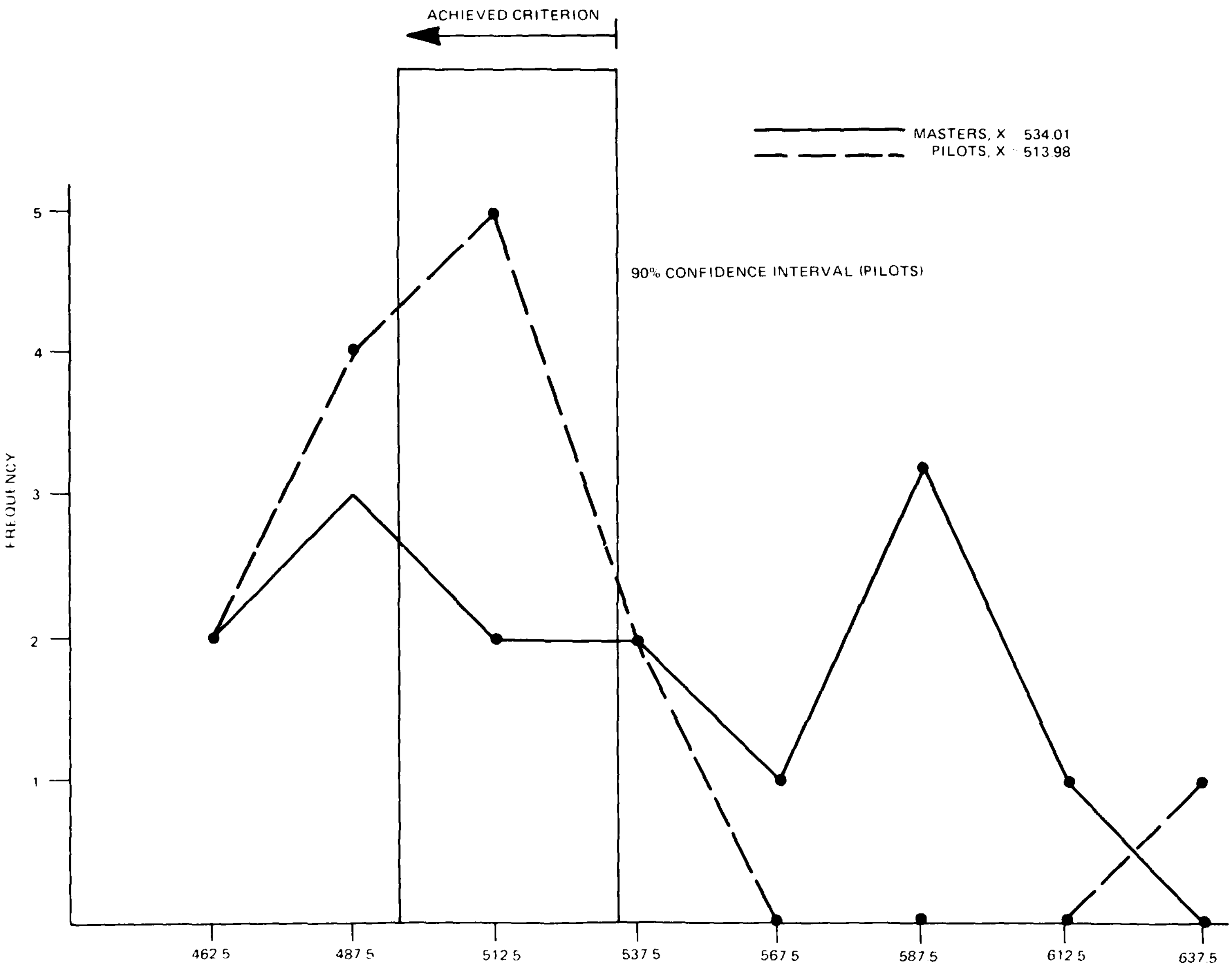

Figure D-2. Frequency Distribution and Confidence Interval, Maximum Swept Path (in feet), Leg 3, 129 Turn

TRAINING OBJECTIVE: 129 Turn

PERFORMANCE MEASURE: Average Swept Path (in feet)

	Masters	Pilots
$\bar{X}$	252.81	252.99
SD	28.28	38.88
90% Confidence Interval	266.19 to 239.43	271.38 to 234.60

Cutoff Score: > 271.38. Subjects with scores > 271.38 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	13	1
Masters	10	4

χ^2 = (with Yates Correction) = 0.974, not significant

Figure D-3. Summary of Data and Contingency Table, Average Swept Path (in feet), Leg 3, 129° Turn

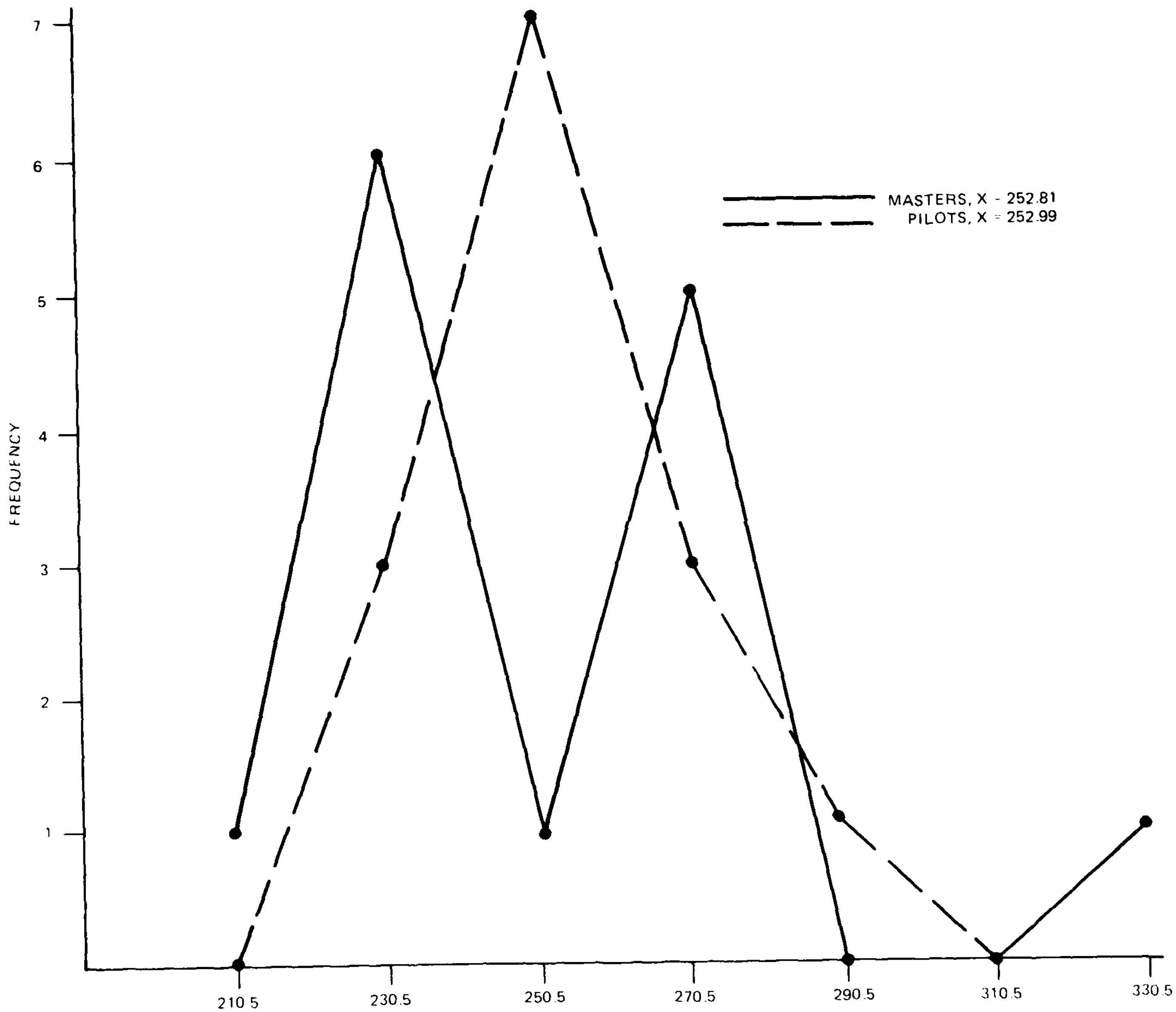

Figure D-4. Frequency Distribution, Average Swept Path (in feet), Leg 3, 129° Turn

TRAINING OBJECTIVE: 129 Turn

PERFORMANCE MEASURE: Maximum Ratio Swept Path

	Masters	Pilots
$\bar{X}$	0.70326	0.66443
SD	0.0589	0.0462
90% Confidence Interval	0.73112 to 0.67539	0.68628 to 0.64258

Cutoff Score: $\geq$ 0.68628. Subjects with scores $<$ 0.68628 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	10	4
Masters	5	9

$\chi^2 = 3.5897$, $p < 0.05$

χ^2 = (with Yates Correction) = 2.29, $p < 0.10$

Figure D-5. Summary of Data and Contingency Table, Maximum Ratio Swept Path, Leg 3, 129 Turn

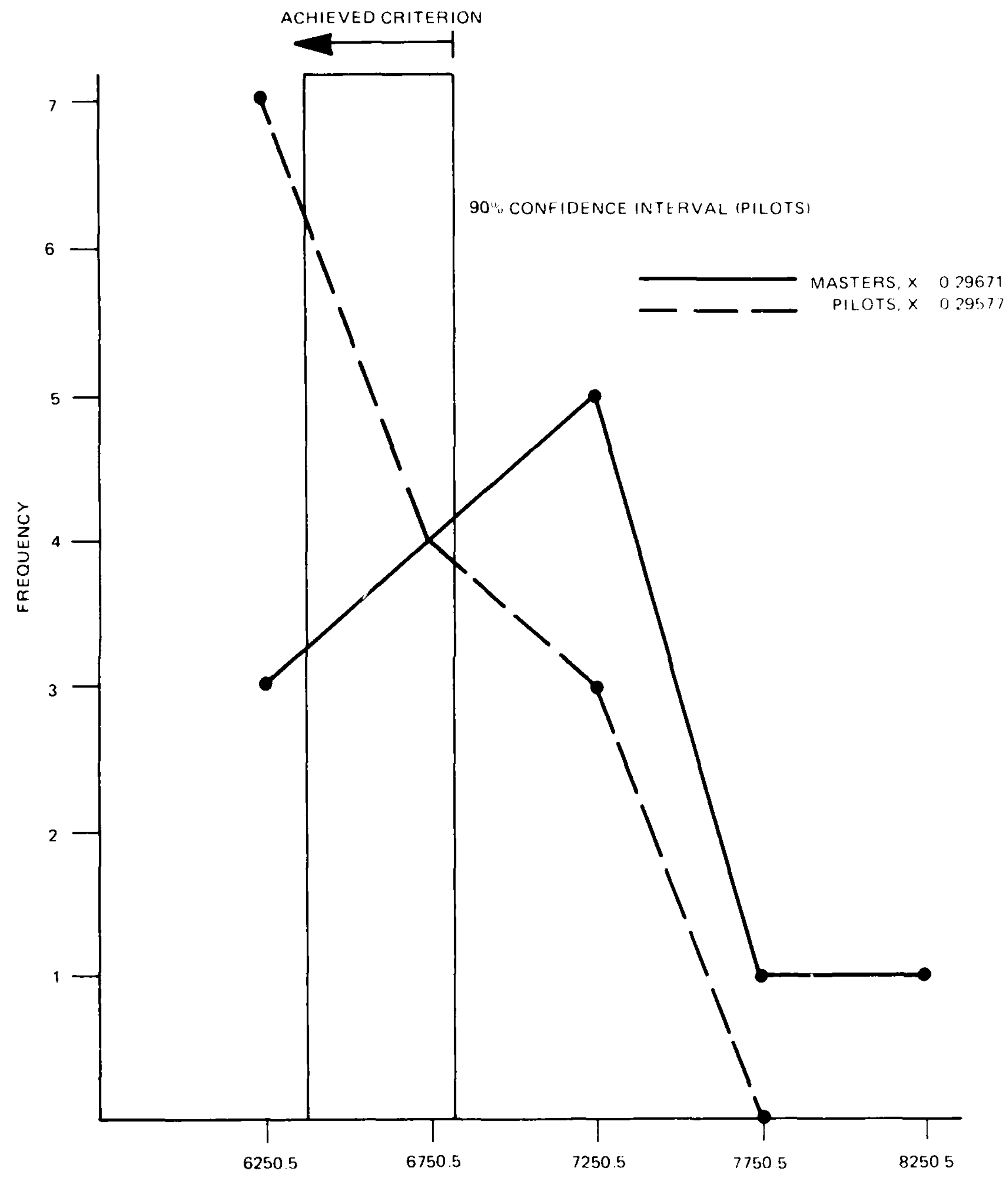

Figure D-6. Frequency Distribution and Confidance Interval, Maximum Ratio Swept Path, Leg 3, 129 Turn

TRAINING OBJECTIVE: 129 Turn

PERFORMANCE MEASURE: Average Ratio Swept Path

	Masters	Pilots
$\bar{X}$	0.29671	0.29577
SD	0.0266	0.0140
90% Confidence Interval	0.30929 to 0.28413	0.30239 to 0.78914

Cutoff Score: $>$ 0.302939. Subjects with scores $>$ 0.30239 are considered not to have achieved criterion.

	Achieved Criterion	Not Achieved Criterion
Pilots	10	4
Masters	9	5

χ^2 = (with Yates Correction) = 0, not significant

Figure D-7. Summary of Data and Contingency Table, Average Ratio Swept Path, Leg 3, 129 Turn

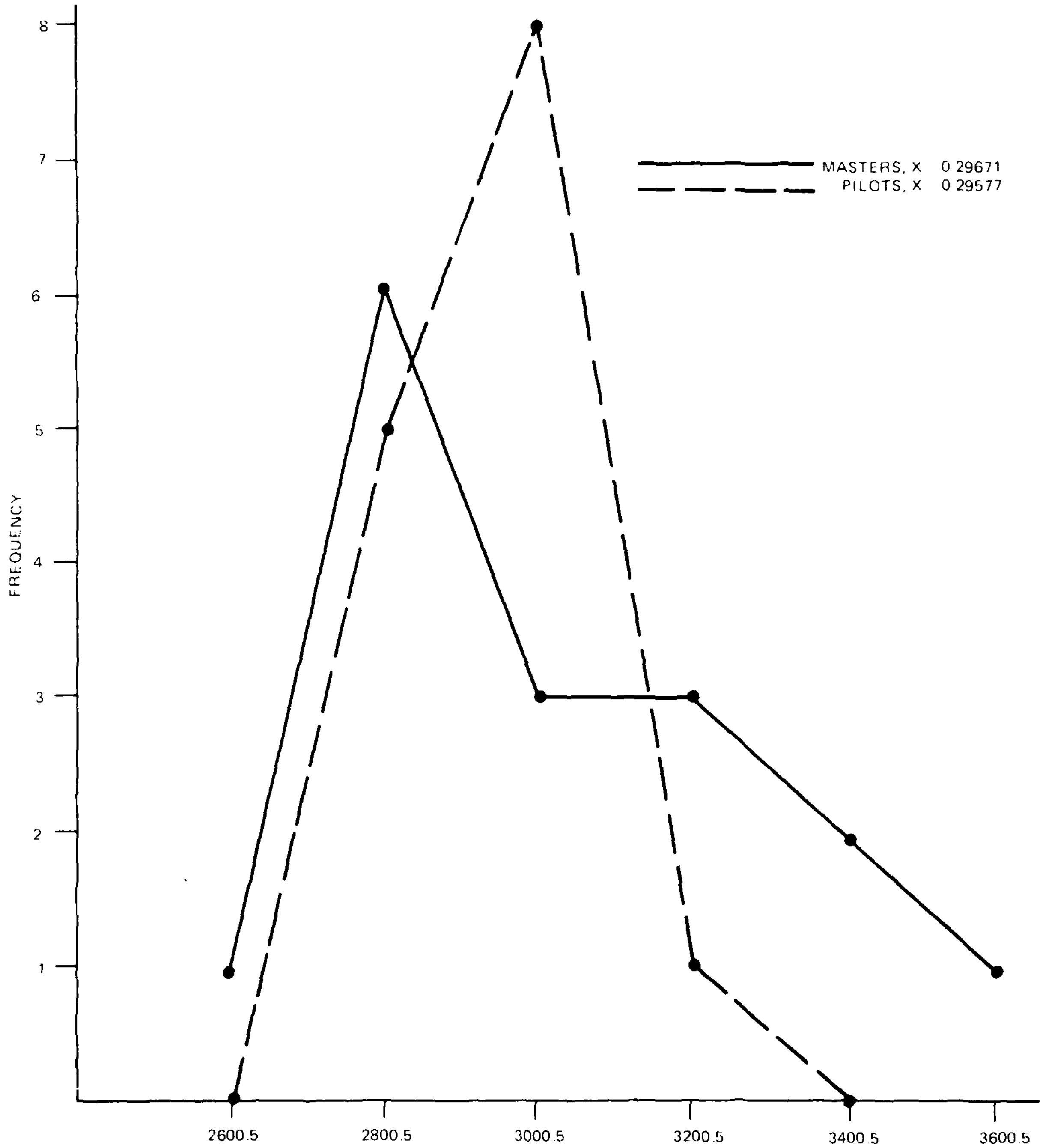

Figure D-8. Frequency Distribution, Average Swept Path, Leg 3, 129 Turn

		Rudder	RPM Ahead	RPM Astern	Thruster
	$\bar{x}$	49.92	31.57	–	28.33
Masters	S.D.	21.81	20.99	–	26.09
	n	14	14	–	5
	$\bar{x}$	58.57	37.85	18	38.33
Pilots	S.D.	7.15	26.96	–	20.86
	n	14	14	7	10
	t*	1.410	0.688	–	0.808
	df	26	26	–	13

*All comparisons of means for Masters and Pilots are not significant.

Figure D-9. Rudder, Engine, Thruster Percent Remaining for Masters and Pilots, Leg 3, 129 Turn

APPENDIX E

PERFORMANCE MEASURES APPENDICES

LEG 4

TRAINING OBJECTIVE: SHIPHANDLING IN RESPONSE TO PROPULSION FAILURE IN VICINITY OF BRIDGE AND SHOAL

LIST OF ILLUSTRATIONS

Number

E-1 to E-14	Track Plots, Masters, Leg 4, Propulsion Failure
E-15 to E-28	Track Plots, Pilots Leg 4, Propulsion Failure
E-29	Percent of Rudder, Engine, and Thruster Remaining, Leg 4, Propulsion Failure

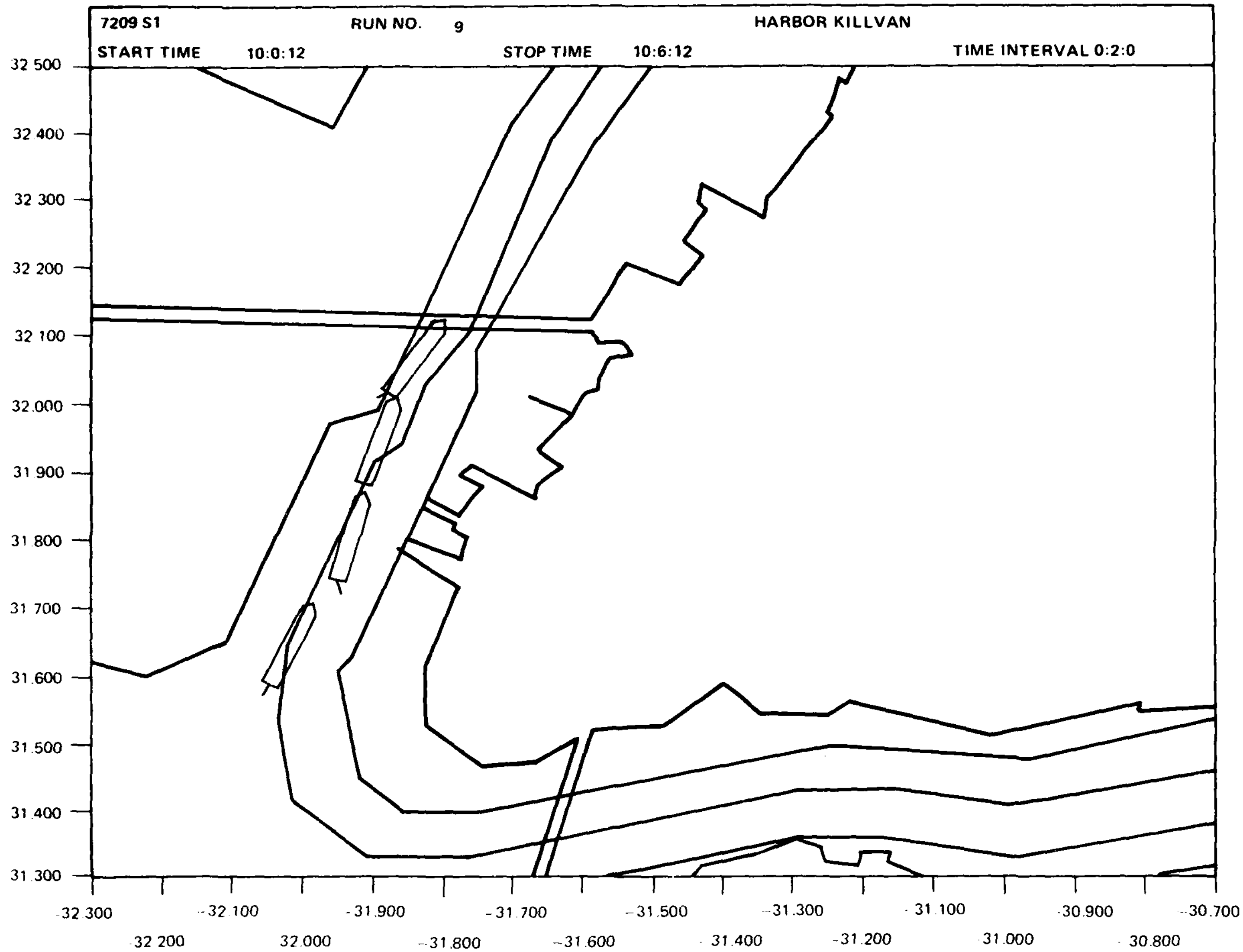

Figure E-1. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E-2. Track Plots, Masters, Leg 4, Propulsion Failure

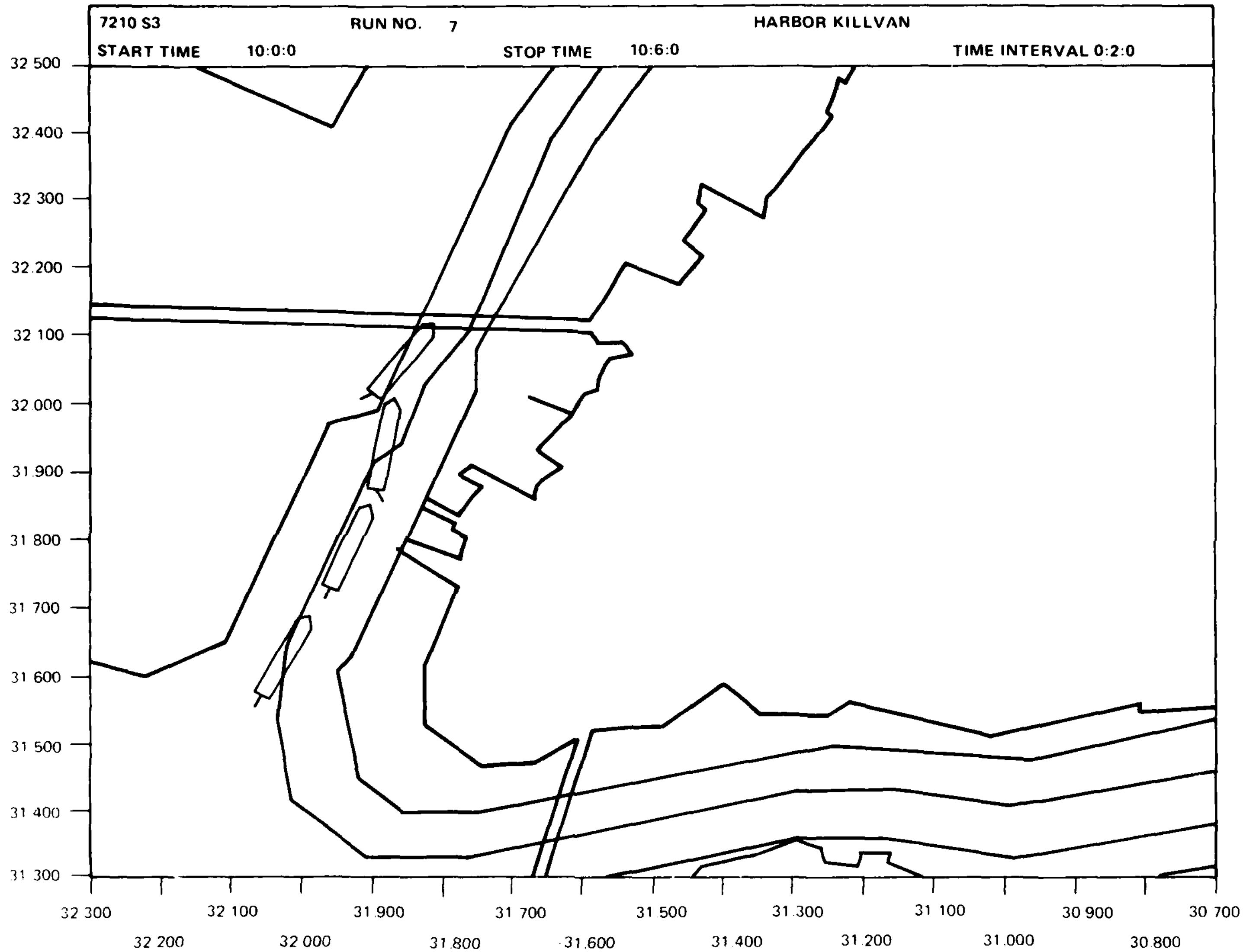

Figure E-3. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E-4. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E-5. Track Plots, Masters, Leg 4, Propulsion Failure

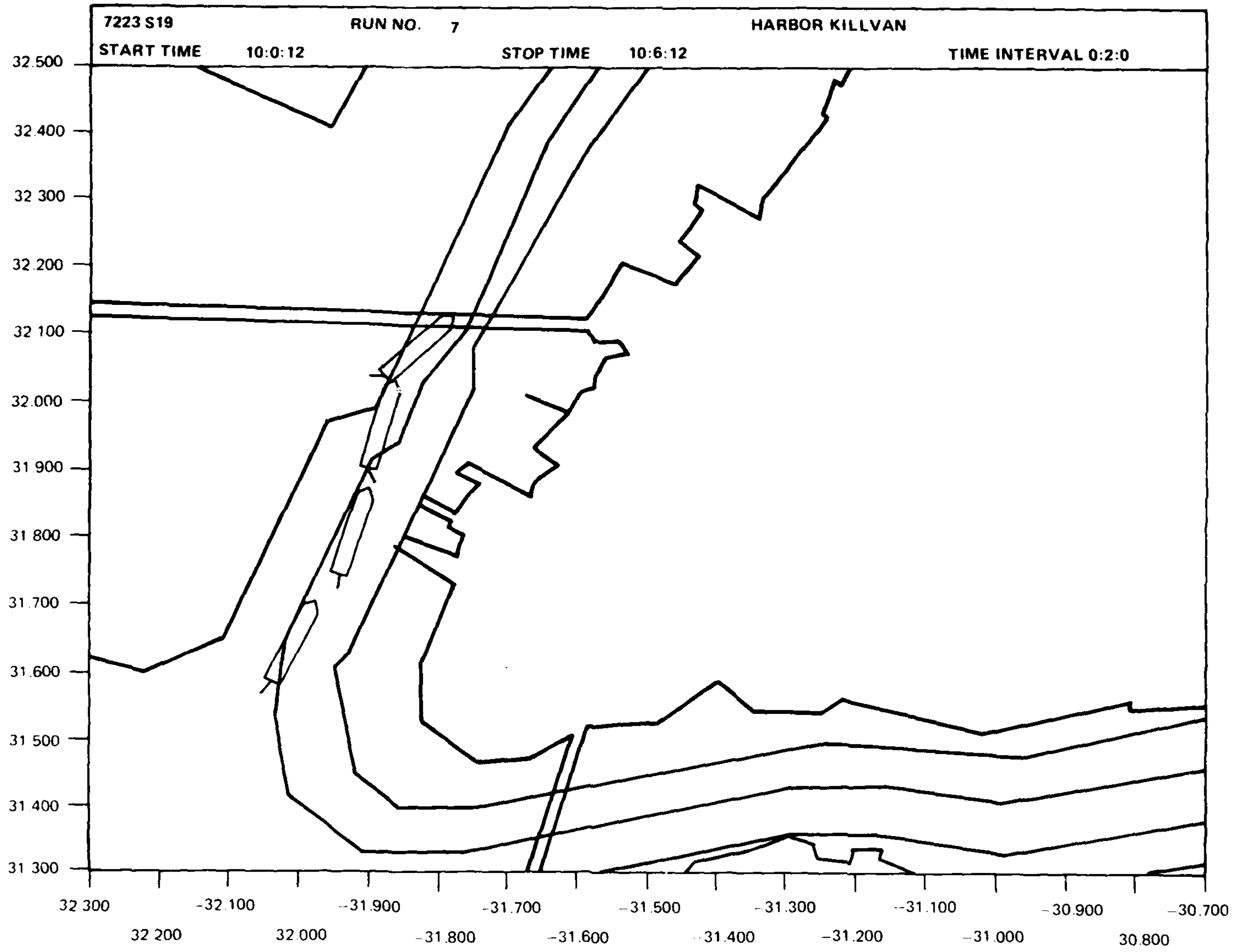

Figure E-6. Track Plots, Masters, Leg 4, Propulsion Failure

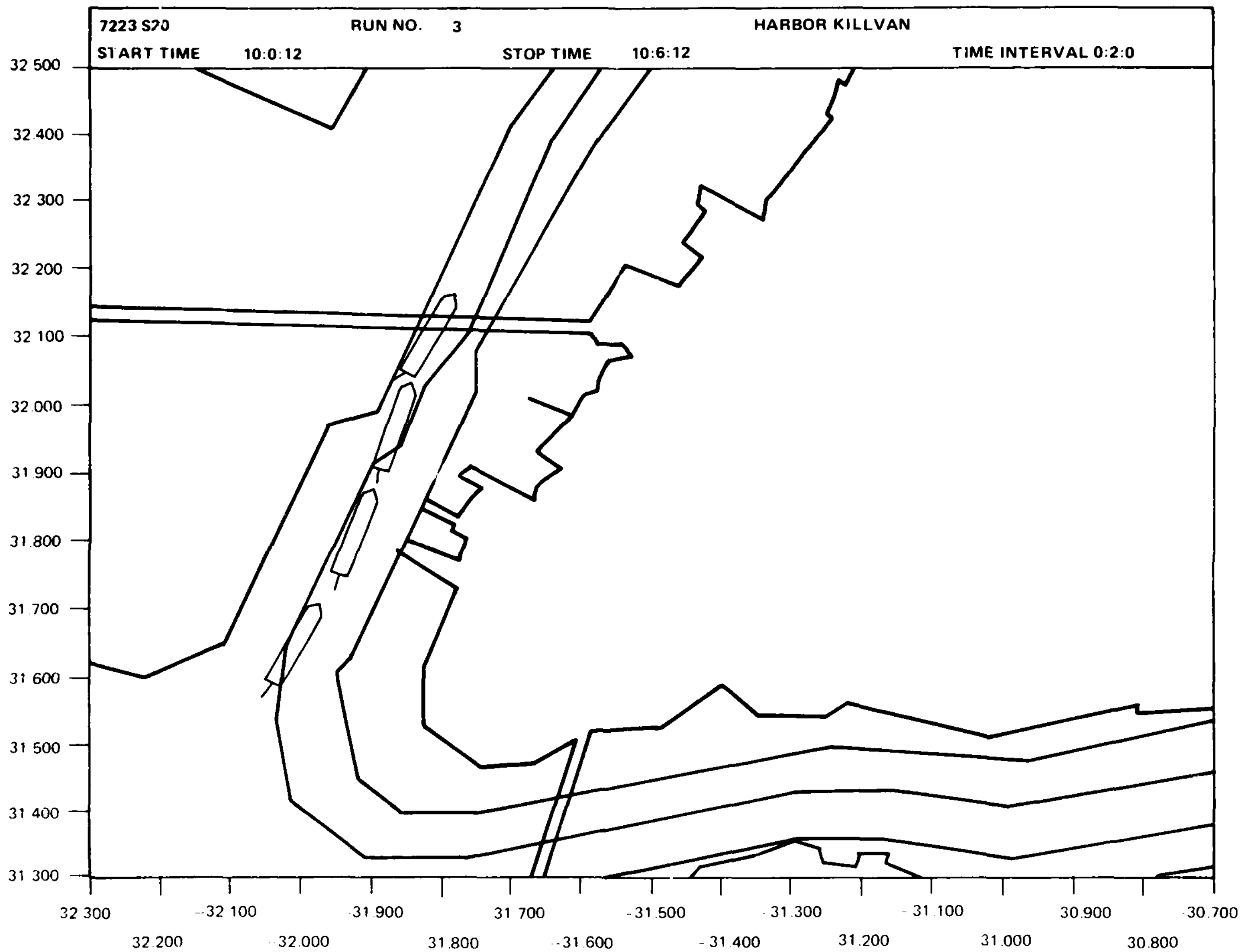

Figure E-7. Track Plots, Masters, Leg 4, Propulsion Failure

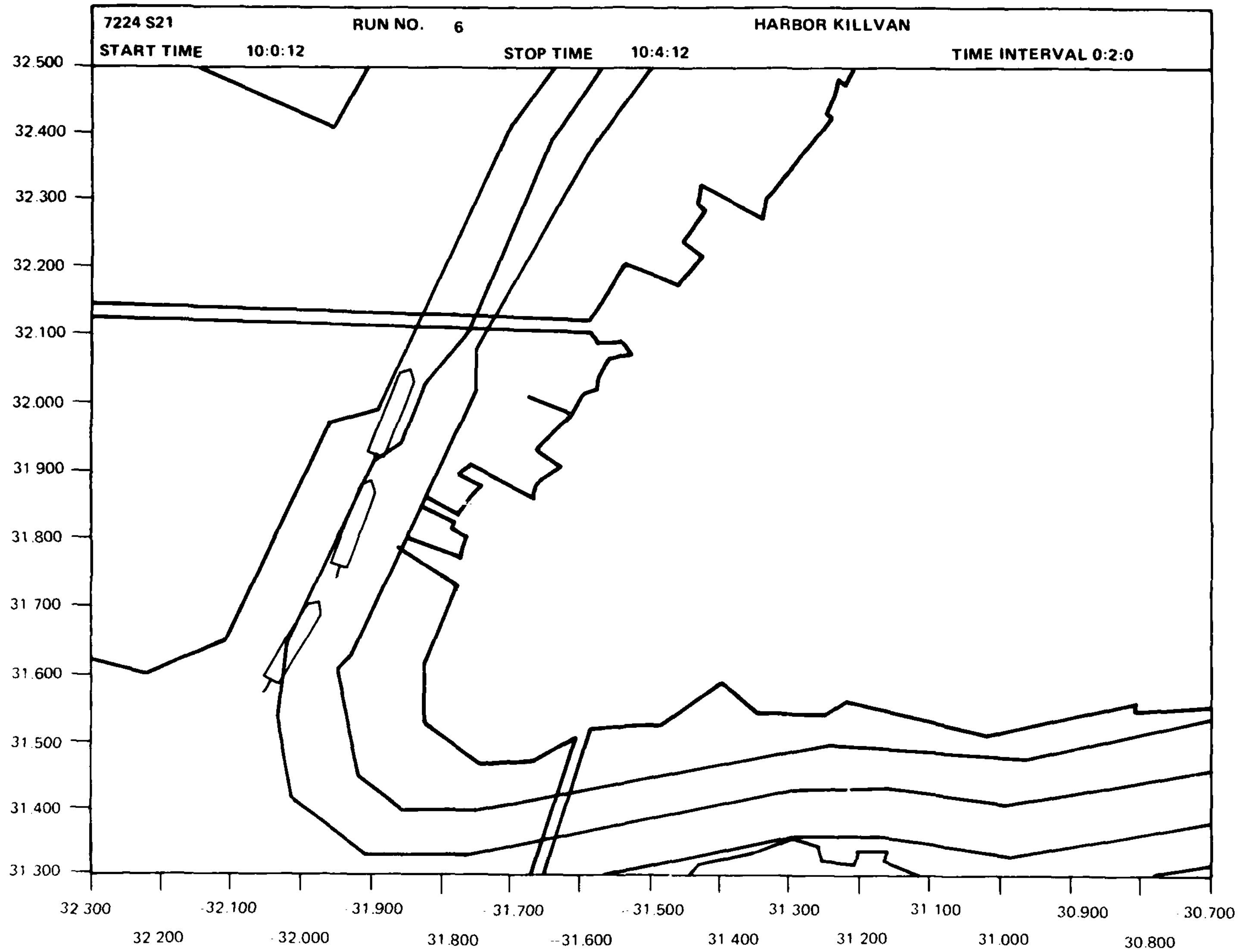

Figure E-8. Track Plots, Masters, Leg 4, Propulsion Failure

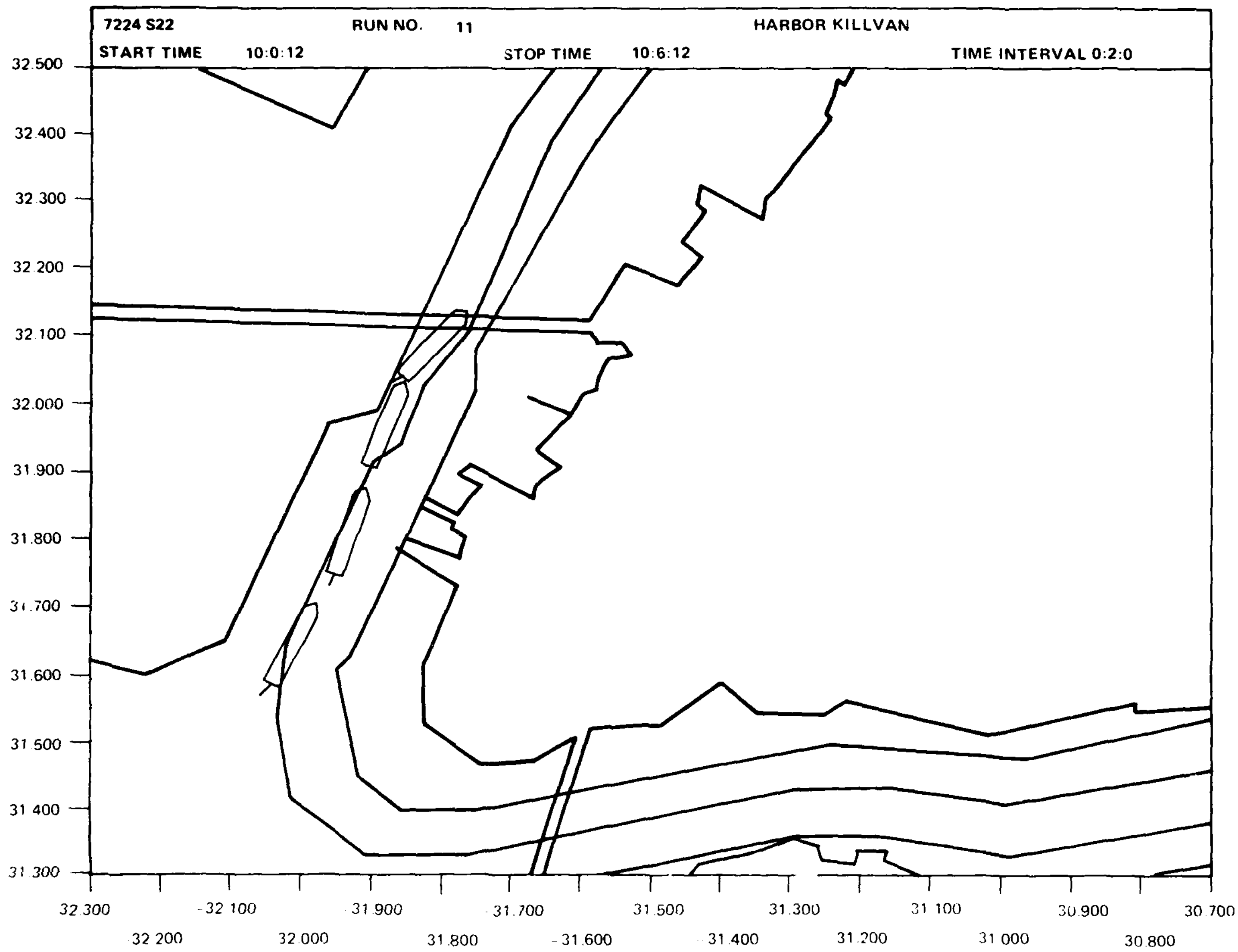

Figure E-9. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E-10. Track Plots, Masters, Leg 4, Propulsion Failure

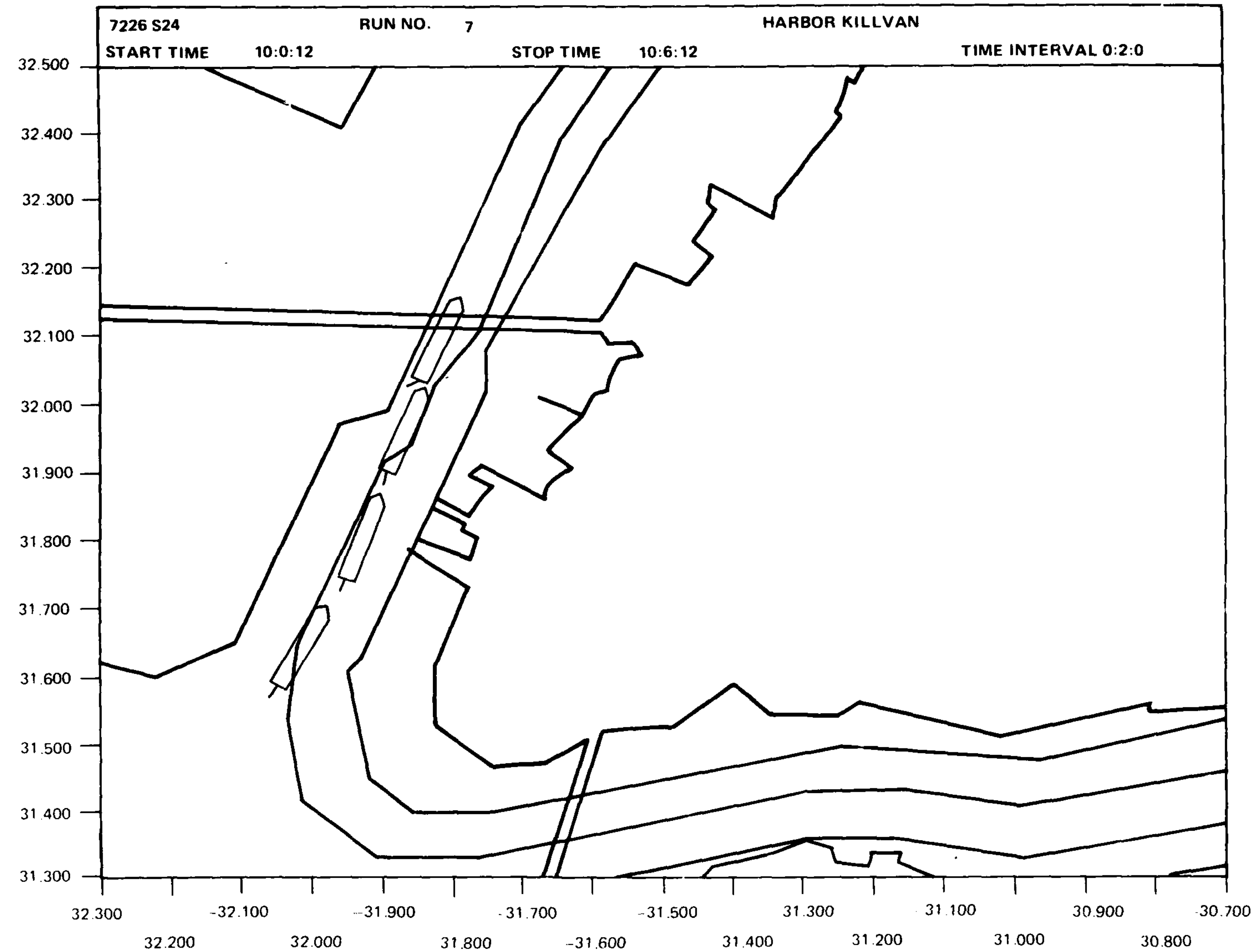

Figure E-11. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E 12. Track Plots, Masters, Leg 4, Propulsion Failure

Figure E-13. Track Plots, Masters, Leg 4, Propulsion Failure

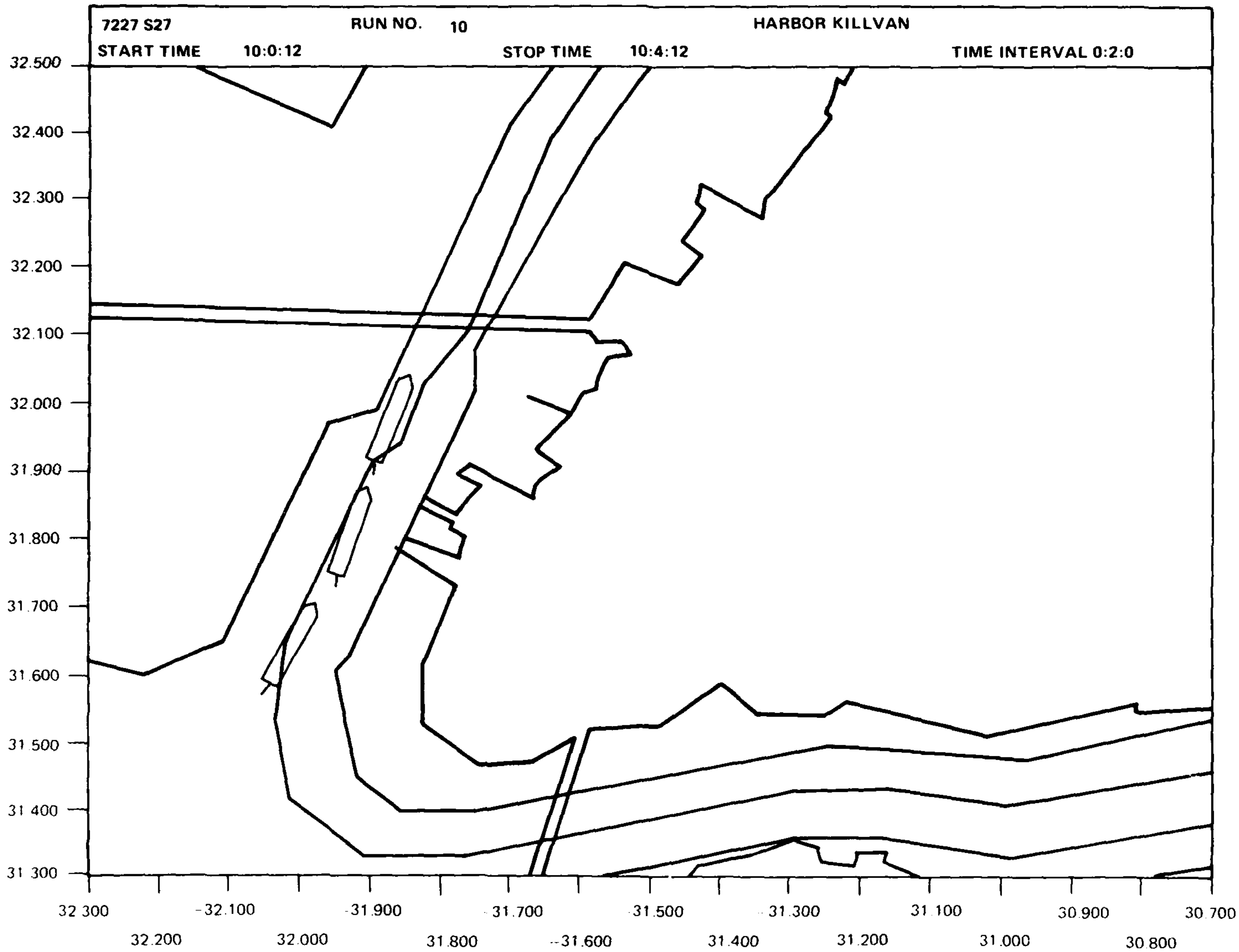

Figure E-14. Track Plots, Masters, Leg 4, Propulsion Failure

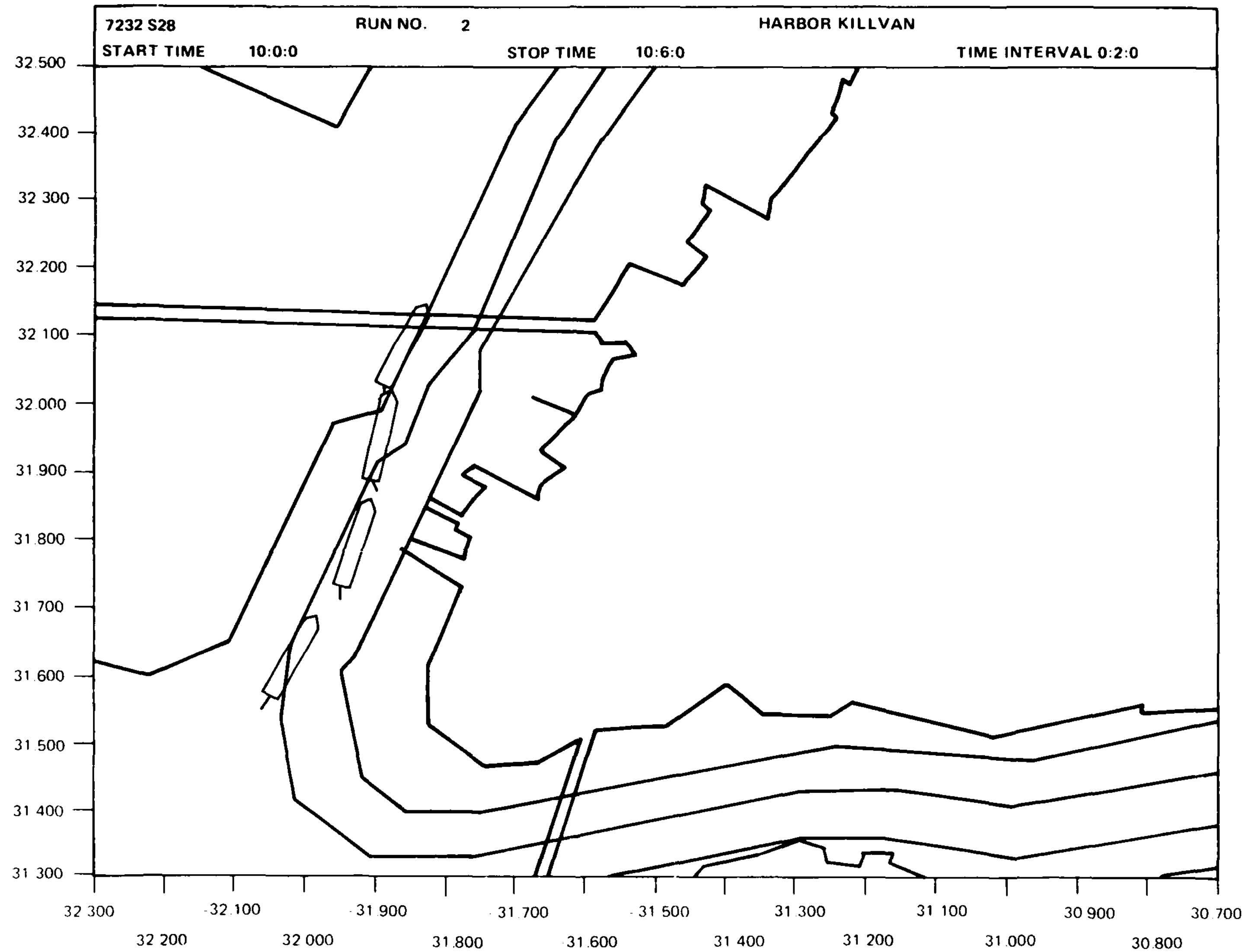

Figure E-15. Track Plots, Pilots Leg 4, Propulsion Failure

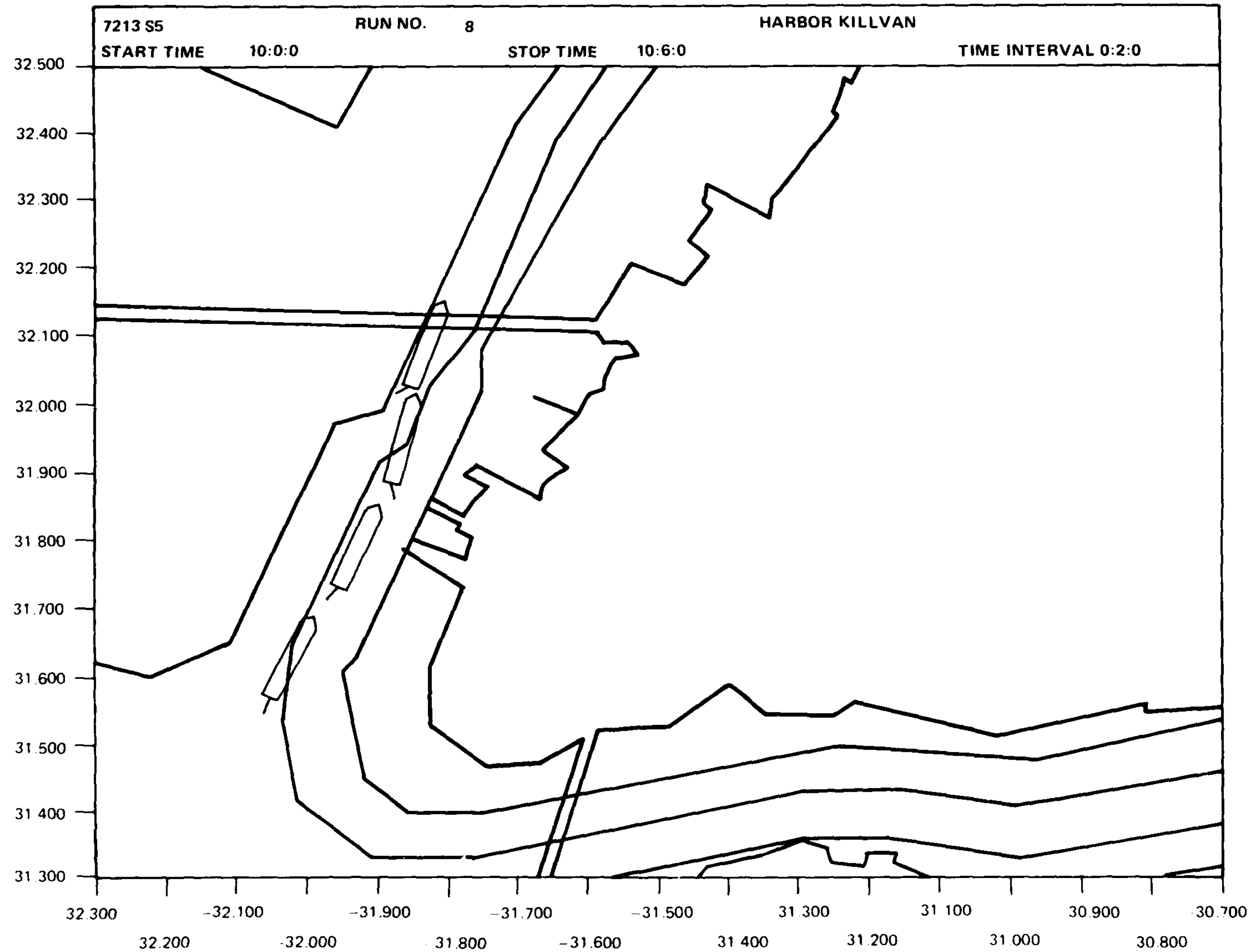

Figure E-16. Track Plots, Pilots Leg 4, Propulsion Failure

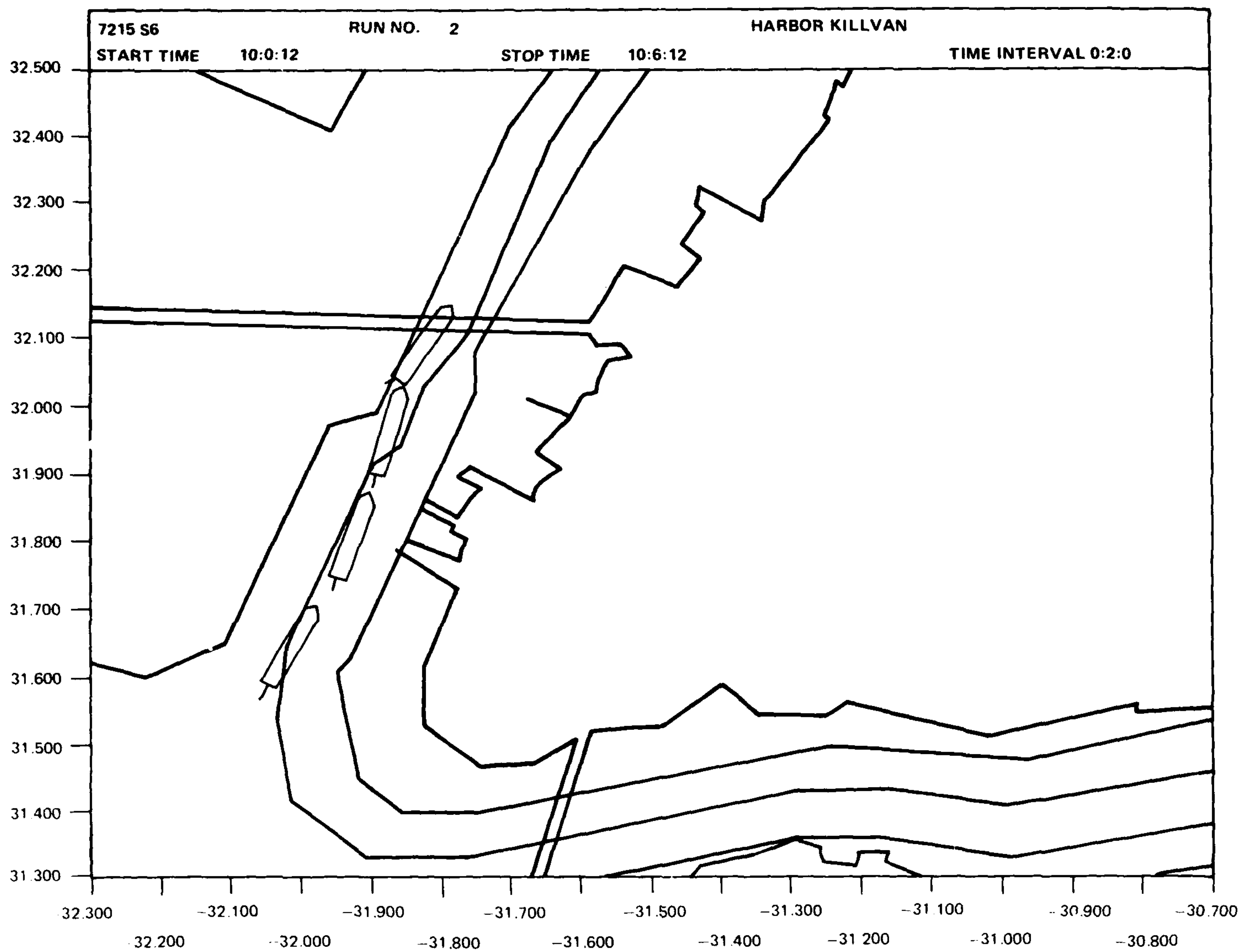

Figure E-17. Track Plots, Pilots Leg 4, Propulsion Failure

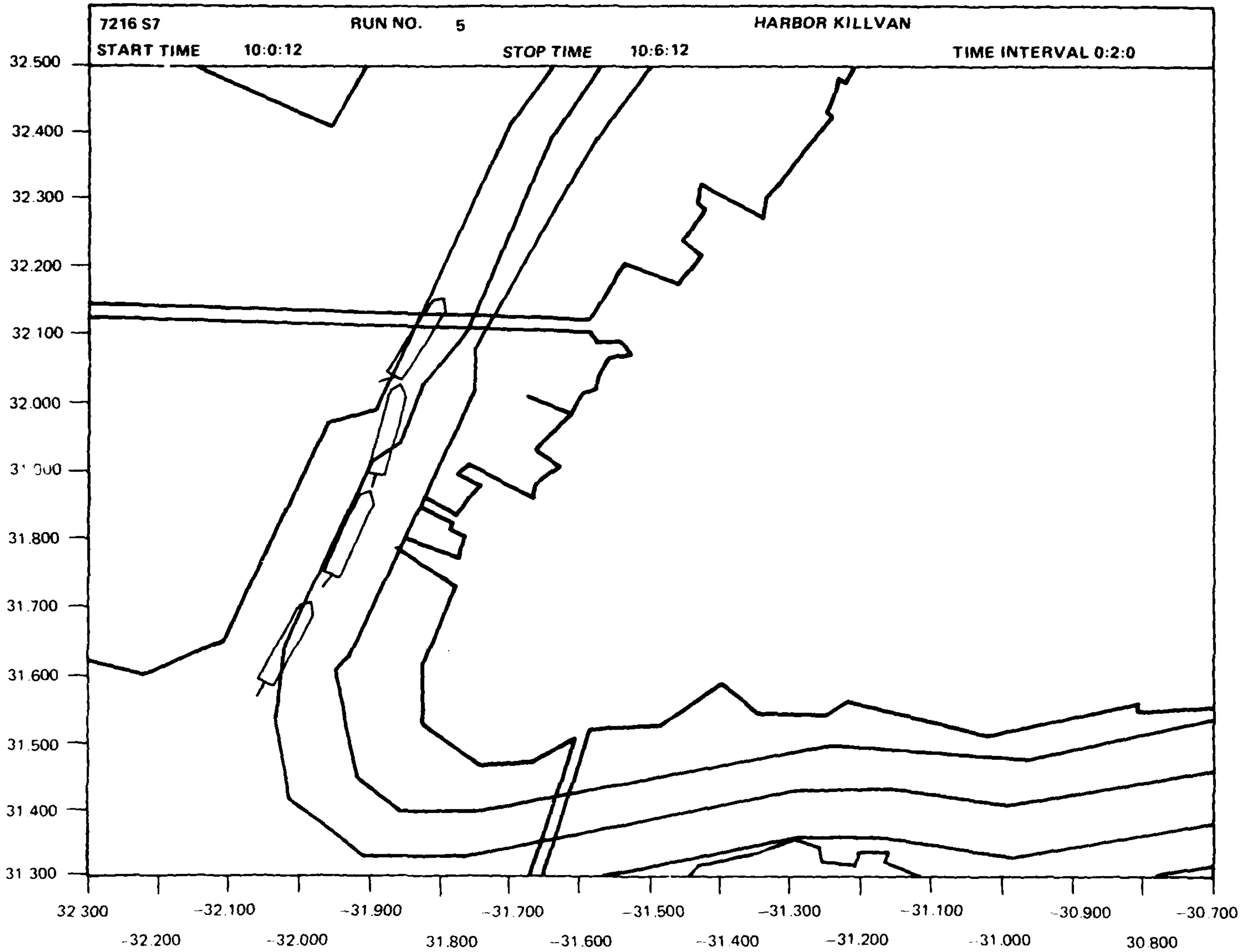

Figure E-18. Track Plots, Pilots Leg 4, Propulsion Failure

Figure E-19. Track Plots, Pilots Leg 4, Propulsion Failure

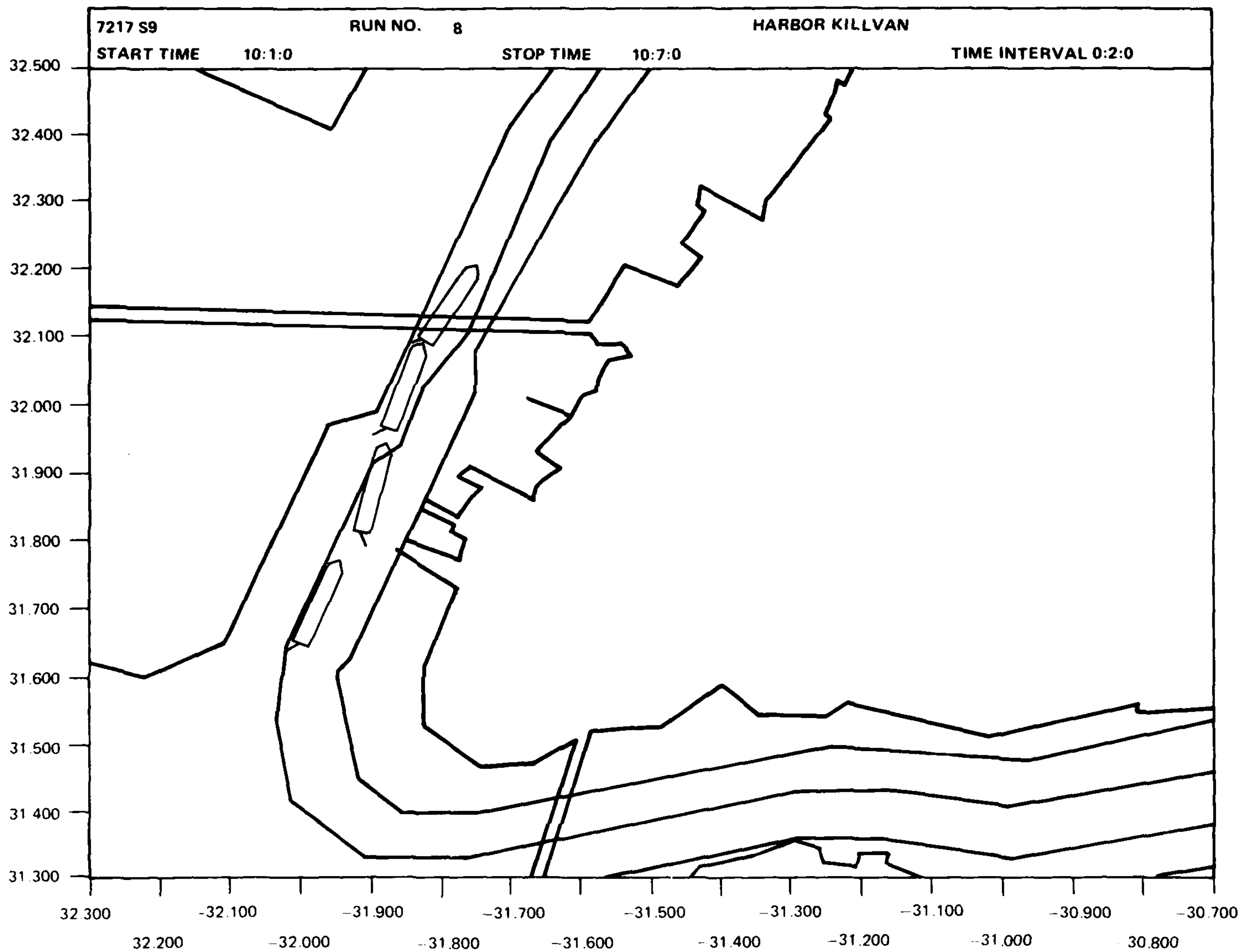

Figure E-20. Track Plots, Pilots Leg 4, Propulsion Failure

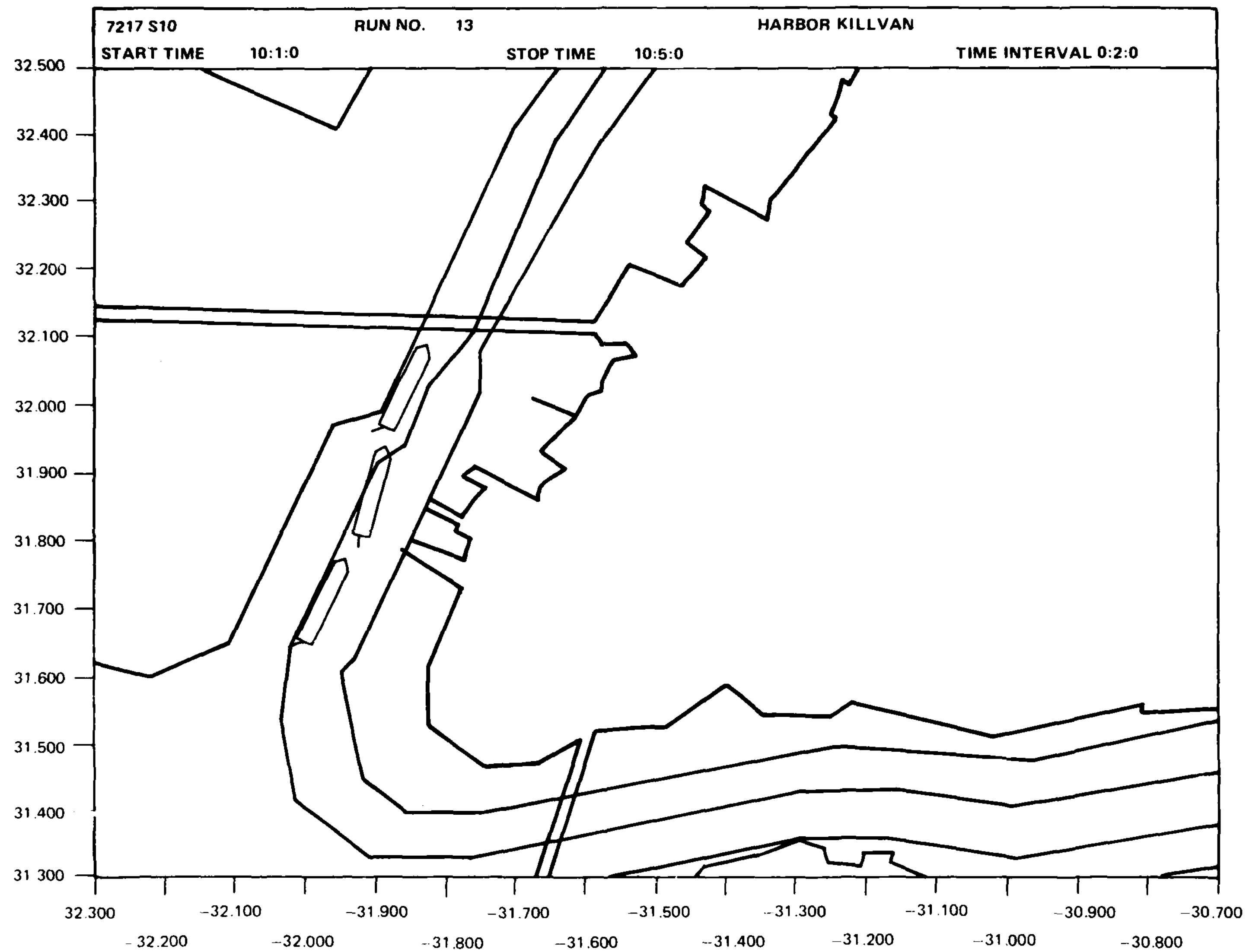

Figure E-21. Track Plots, Pilots Leg 4, Propulsion Failure

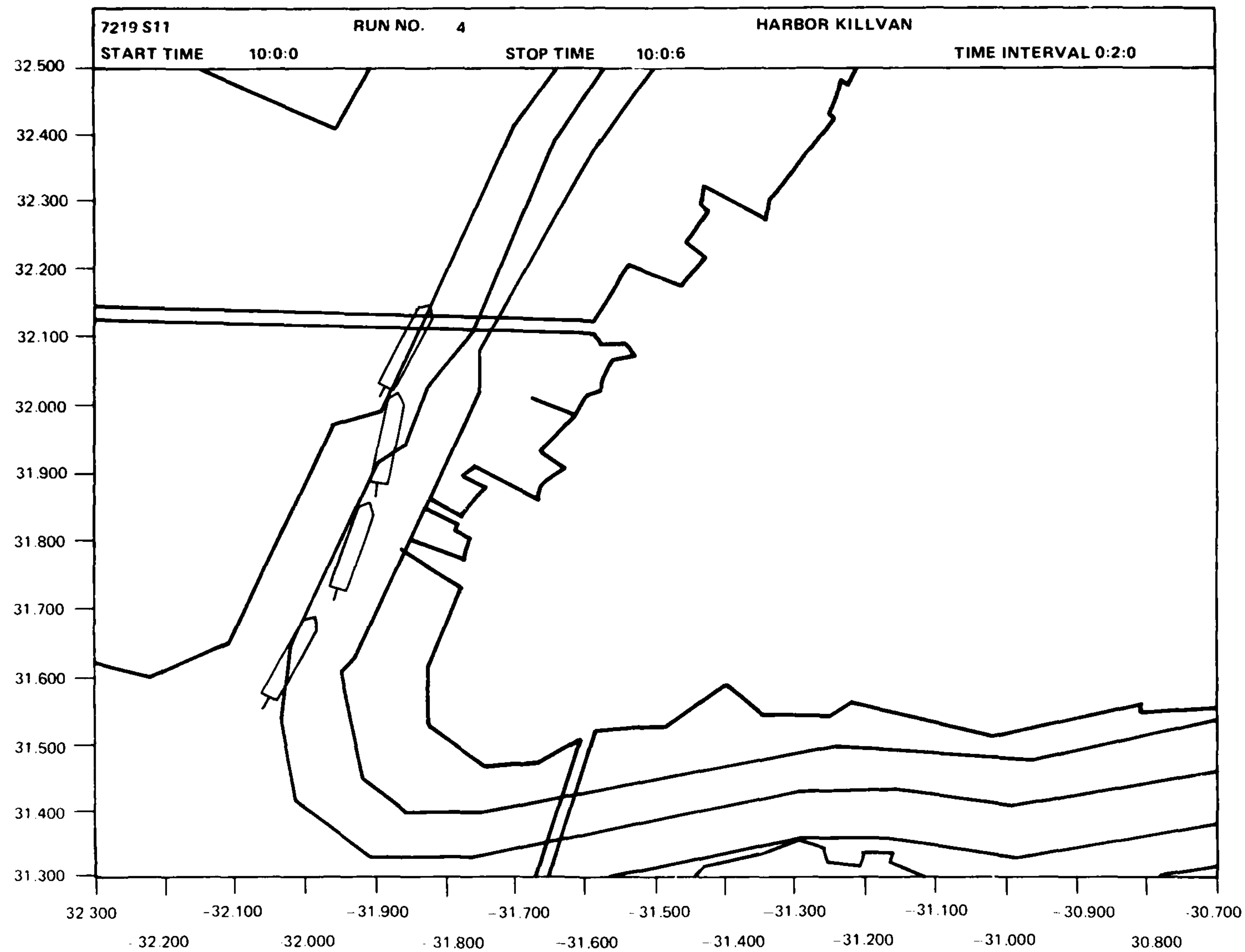

Figure E-22. Track Plots, Pilots Leg 4, Propulsion Failure

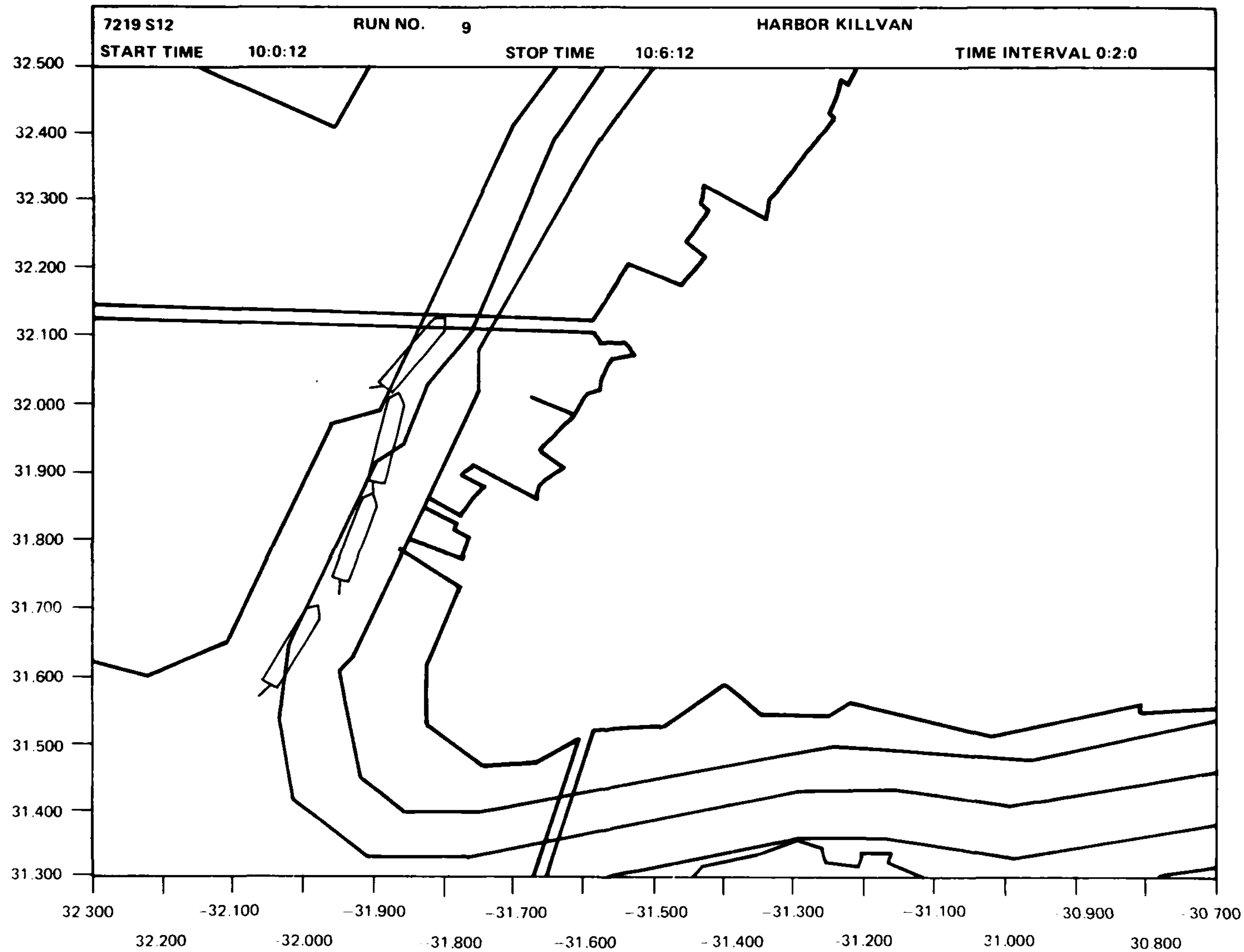

Figure E-23. Track Plots, Pilots Leg 4, Propulsion Failure

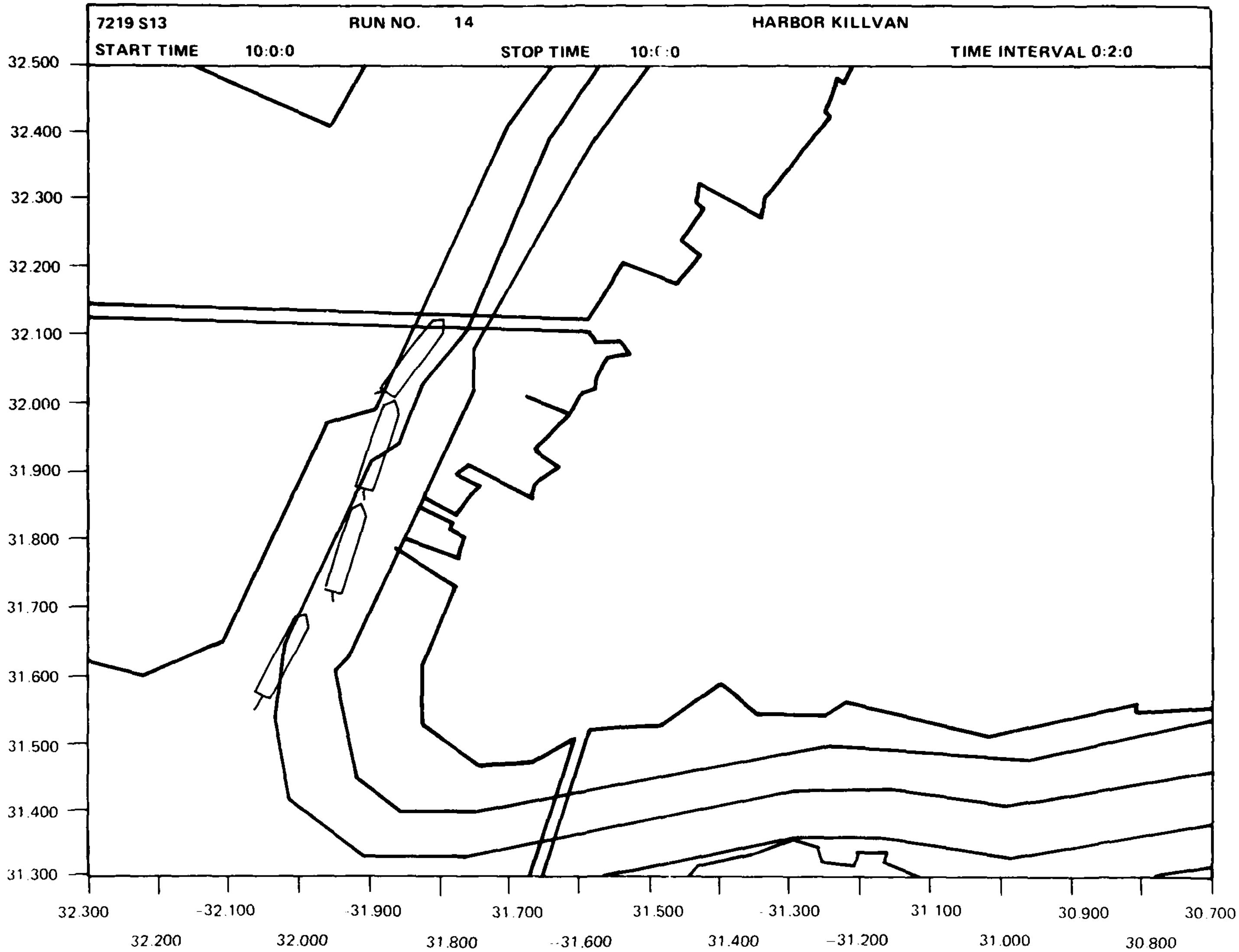

Figure E-24. Track Plots, Pilots Leg 4, Propulsion Failure

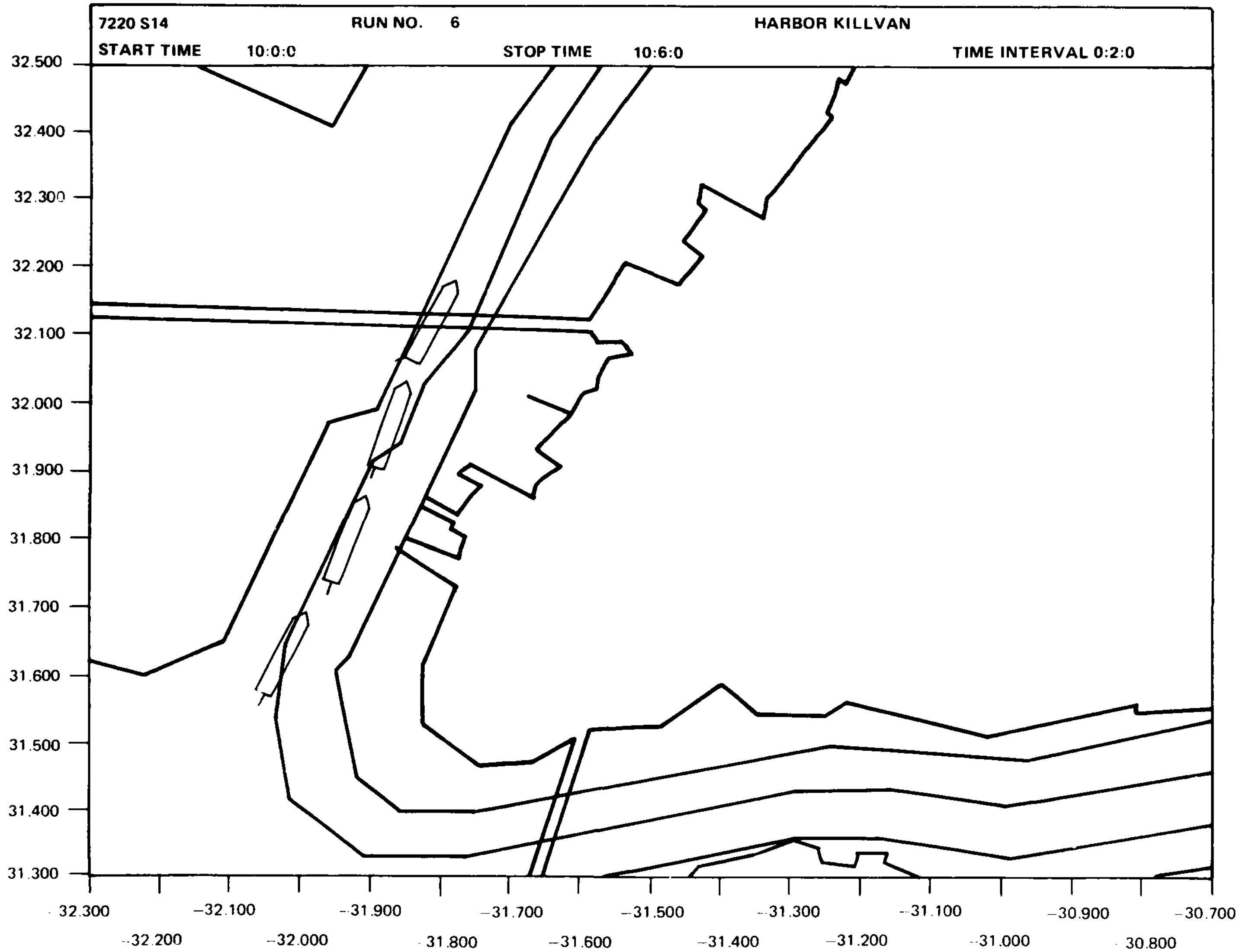

Figure E-25. Track Plots, Pilots Leg 4, Propulsion Failure

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SIMULATORS FOR MARINER TRAINING AND LICENSING, PHASE 3, TASK C.--ETC(U)
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Figure E-26. Track Plots, Pilots Leg 4, Propulsion Failure

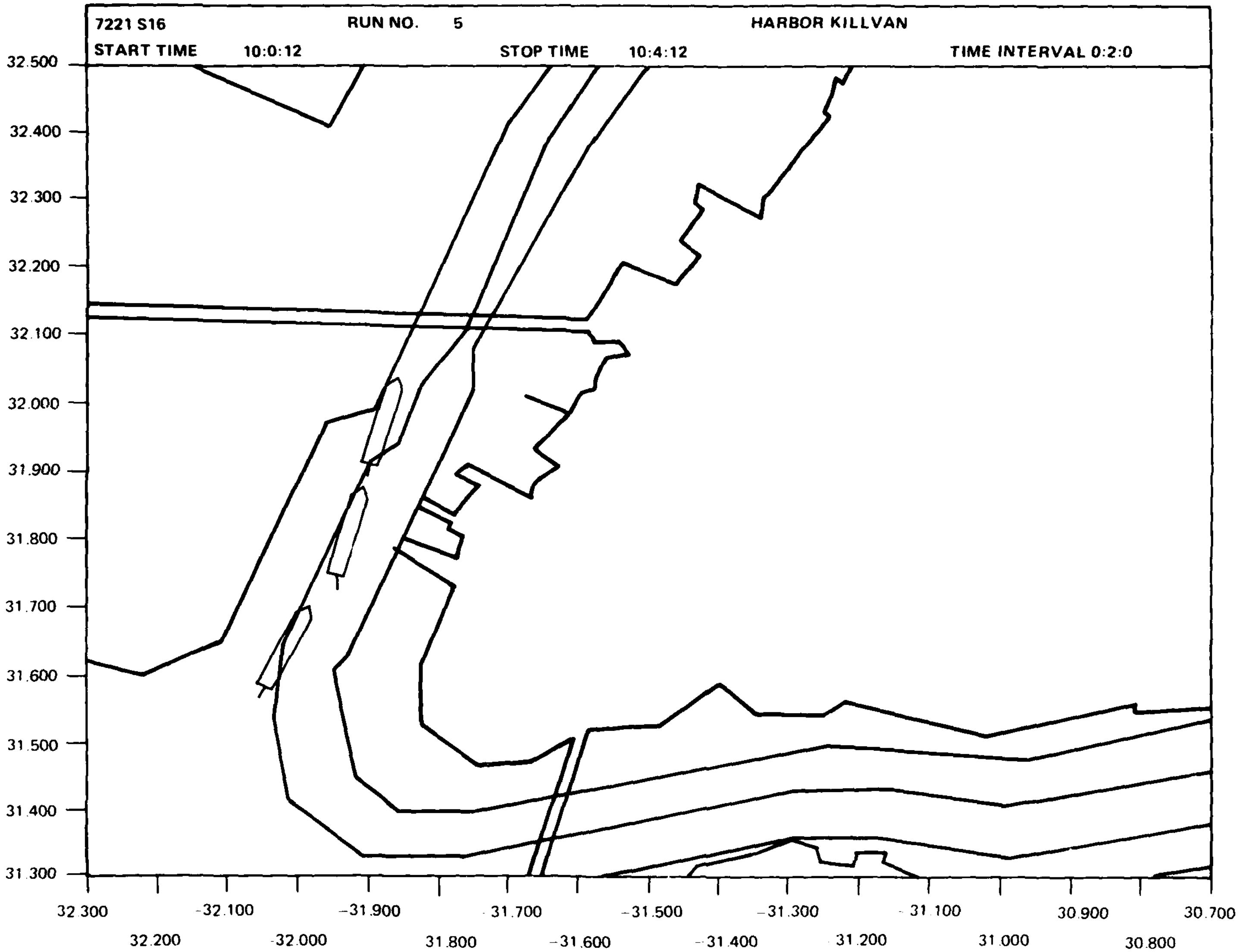

Figure E-27. Track Plots, Pilots Leg 4, Propulsion Failure

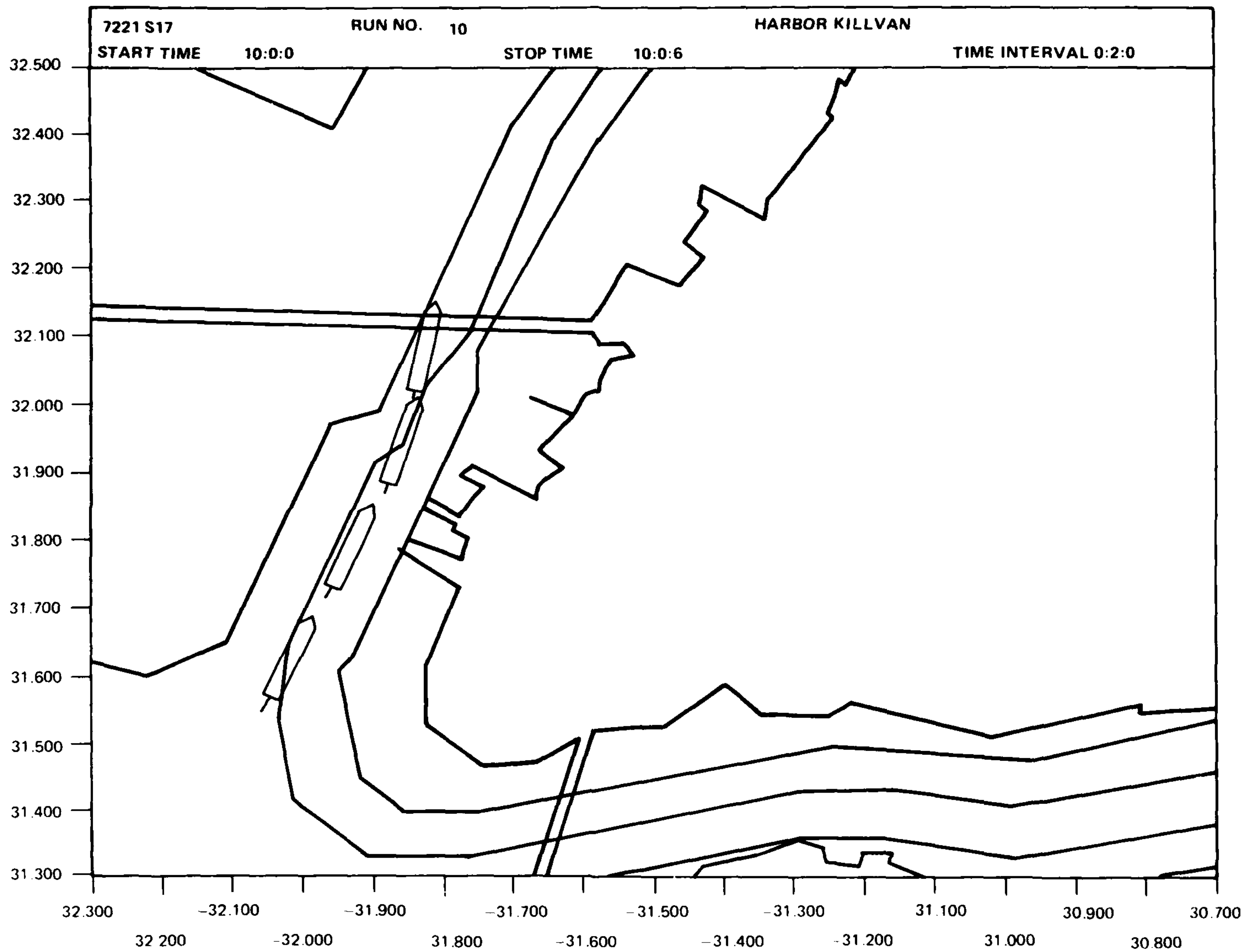

Figure E-28. Track Plots, Pilots Leg 4, Propulsion Failure

		Rudder	RPM Ahead	RPM Astern	Thruster
	$\bar{x}$	53.36	64.29	–	27.87
Masters	S.D.	9.6	35.70	–	16.71
	n	14	14	–	13
	$\bar{x}$	51.43	56.21	–	29.91
Pilots	S.D.	8.48	25.41	–	16.74
	n	14	14	–	14
	t*	0.391	0.690	–	0.323
	df	26	26	–	25

*All comparisons of means for Masters and Pilots are not significant.

Figure E-29. Rudder, Engine, Thruster Percent Remaining for Masters and Pilots, Leg 4, Propulsion Failure

APPENDIX F

INSTRUCTIONAL TECHNIQUES

INTRODUCTION

As the feasibility of training shiphandling skills on a simulator becomes more and more evident, certain advantages of simulator training over on-ship training are immediately apparent. The high cost and scheduling problems of operating a training ship, the danger involved, and the limitations placed by environmental factors on the types of training possible can be offset to some degree by training on a simulator, especially in situations that are particularly dangerous or naturally infrequent. In this way, benefits can be accrued simply by using the simulator as if it were an actual ship, and striving for as much realism as possible in the training scenarios. However, an examination of the literature on principles of training suggests that the simulator provides an opportunity to employ what is known about the psychology of learning towards maximizing the efficiency and effectiveness of training programs. The new trend in simulatr instruction is to present material, not necessary to duplicate the real-life situation, in such a way as to ensure that it is understood and remembered, promoting the development of the skills needed to perform the tasks involved on the job.

The literature available describing this trend falls into four broad categories. First, the dsign of the curriculum is of critical importance. Procedures for determining precisely what is to be taught are being developed, and the order of presentation is being shown to have a great effect on learning efficiency.

The second of these broad areas is that concerning research on cognitive styles. It is becoming recognized that people have various ways of acquiring information from the environment, processing the information, and incorporating it into their long term memory. Cognitive psychologists are classifying the different strategies used to process and store information along various parameters, and are developing ways of classifying people in terms of their predominant cognitive strategies. Attempts, are being made, therefore, to design training programs which present material that is structured to correspond to the individual's cognitive structures. For example, certain people tend to use different hierarchies of organization, or different parameters of categorization, and material can be presented with these organizational tendencies in mind, to make the task of learning and remembering that much easier for each individual. Research on specific cognitive styles and how training can be related to these is examined here.

LITERATURE REVIEW

CURRICULUM DESIGN

Perhaps the best way of addressing the issue of curriculum design is through employment of the Armed Forces Instructional Systems Development (ISD) technique. This technique provides a systematic and standardized approach toward the various aspects of curriculum design such as task analysis, assessment of requirements, definition of training objectives, assessment of trainability, estimation of benefits, etc., and thus represent perhaps the best way of attacking the problem. Montemerlo and Tennyson (1976) Vineberg and Joiner (1978) provide a description of the development of ISD, an analysis of the concepts involved, and a detailed description of the methodology for designing a training curriculum.

Two other articles have also been located concerning factors of curriculum design. The first, Matlick, Swezey, and Epstein (1980) investigates factor influencing the design of individualized instructional programs. Three major areas are identified and broken down into complex subsets. The three areas are the instructional setting, the focus (equipment, technique, knowledge) and time considerations (fixed or variable schedules). Eight controlling influences on instructional programs are also described: 1) time available, 2) instructional personnel, 3) facilities, 4) instructional management, 5) student population and characteristics, 6) course type, 7) instructive methods, 8) media/materials/devices. The paper assumes that training standards will be more or less fixed and so four approaches to training can be used, with either fixed or variable curricula in various combinations with either fixed or variable training times. Some advantages anu disadvantages of each approach are discussed, and some existing training programs are described. (None of these programs, however, deal directly with simulated shiphandling.) The major idea here is to strike a balance between required standards, allotted time, and the capabilities of each trainee.

The other paper relating to curriculum design is Bergan, Cancelli, and Towstopiat (1978). This begins with the premise that most training tasks can be broken down and taught as hierarchies of simpler skills. In order to make sure the hierarchies are correctly designed, the authors say three hypotheses must be tested. First, that the specific trainee responses called for in training represent response classes applicable under different stimulus conditions; second that subordinate skills in the hierarchies are indeed prerequisite to superordinate ones; and third, that prerequisite skills mediate the transfer of superordinate ones. The paper investigates ways of testing these hypotheses and describes in considerable detail the design and analysis of an experiment in which these hypotheses were tested. If, as it seems from the literature, it is decided that training by components or chains in a superior technique, the ideas outlined in this paper may prove useful in determining the proper relationship of the components and chains.

COGNITIVE STYLES

One article pertaining to cognitive styles attempts to draw comparisons between the semantic or organizational structure of the learning material and the learner's cognitive constructs. In Winn (1976) the author's premise is that an effective instructional system should present information so that cognitive structures resulting from instruction correspond to the structure of the content to be learned. He discusses methods for describing content-structure and cognitive structure and for comparing the two, then presents and illutrates methods for studying changes in cognitive structure as a result of instruction.

Cognitive structure is described here as networks of interrelated concepts forming a coherent conceptual domain. Learning takes place when cognitive structure changes and so instruction should relate the nature of individual concepts and also the relations between them. Thus, an analysis must be performed to determine such relations. Such analyses should be concerned with observable behaviors and also with learning processes. The author suggests such analyses can be carried out either "rationally" or empirically and describes the procedures by means of a chart:

The author suggests that the important thing is to translate the restructuring of the cognitive construct into an organized series of actions. These actions are called enabling objectives and are concerned with what is to be stored and also what arrangement these things are to be stored in to facilitate retrieval (i.e., what associations are to be emphasized).

These restructuring actions will probably be different for different people and so certain things about the learner must be known if for instance, his ability to grasp concepts and relationships, aptitude for verbal reasoning, aptitudes in spatial abilities (this is suppoed to parallel the idea of closely relating concepts in cognitive space) tendencies in structuring information (field dependence test, visual-haptic test) and abilities to restructure information.

To assess progress, the author suggests deriving matrices of entry concepts and comparing them with post-instruction matrices. He presents mathematical models for making this comparison and for comparing the learner matrices with the ideal matrix of the instructional design.

This article seems particularly important in that it gives a psychological foundation to the contention that scientific curriculum design if of the utmost importance in training.

Another cognitive styles article, Ausburn (1979), postulates a link between learning characteristics (dictated by cognitive style) and learning task requirements. Where the two are compatible, learning is facilitated, but where there is a discrepancy, learning is hindered. In the latter case, the instructional design should bridge the gaps between learning style and task requirements. This is done by performing for the learner tasks which he would ordinarily have to do himself but cannot because of limitations in his cognitive style (supplantation). Thus, instruction should be designed to interact both with task requirements and cognitive style.

The first step in supplantational instruction design is the definition of the basic mental task requirements. Second is the identification of characteristics that might prevent the learner from performing the task. Third is designing an instructional tretment that can supplant the necessary function.

This study investigated the learning of visual comparison tasks by "visuals" vs. "haptics" (the latter are thought to be unable to retain visual images) and supplantation was applied. Two groups each of visuals and haptics saw three slides of machinery: a close-up of a specific control device on a machine, a medium-angle shot, and a long range shot. Then they had to locate the control on a drawn diagram of the whole machine. One group each saw the slides at a time (linear condition) for 3 seconds each and the other groups saw the slides simultaneously (multiple condition) for nine seconds. Both visuals and haptics did better in the multiple condition compared to the linear conditions (visuals did better than haptics in both conditions) but haptics showed significantly more improvement. The idea is that haptics could not store images to perform the linear comparison so the multiple presentation supplanted the process and helped them.

The paper lists other cognitive style dimensions that are testable and explains how these may relate to training. The dimensions identified include: leveling-sharpening, distractability, breadth of categorization, scanning, impulsive-reflective, tolerance for unrealistic experiences, cognitive complexity-simplicity, conceptual style, and grouping preference. Various aspects of a training program should be closely scrutinized to see whether any of these factors could influence the acquisition of certain skills. Alternative strategies might then be developed to assist trainees whose cognitive styles might not be conducive to learning portions of the standard training program.

Another article was located which illustrates the above point. Johnson (1978) describes a study in which trainees with differing degrees of vividness of mental imagery were trained to run an assembly line on simulators with different levels of fidelity. The study showed a situation in which the degree of simulator fidelity caused different training and transfer effects on different subjects, depending on how they scored on a scale of vividness of visual imagery. Thus, it is shown that generalizations about the effects of different treatments cannot be made without taking into account certain learner characteristics which may interact with some instructional variables.

INSTRUCTIONAL TECHNIQUES

The literature that has been placed in this category also points out interactional effects in training. Brown (1978) reports a study which found that students come into the learning situation with certain ideas as to what styles of teaching help them learn best. They rated the actual teaching style they received and it was found there was a positive correlation between the amount of congruence between preferred and perceived teaching styles and high grades. Thus, it might pay to make an effort to teach a student in the manner which he feels is most beneficial. Also, the interactive effect is shown; no one style of teaching may ever be found to be best since the learner's preference seems to have an effect on the relative effectiveness of different teaching strategies.

Not only do teaching strategies interact with learner variables, but they seem to interact with one another as well. Briggs, Naylor, and Fuchs (1975) demonstrate just such a case. This experiment investigated the relative efficacy of whole-task and progressive-part training strategies. It was found that as a task becomes more complex, the progressive-part technique (which is less effective for simple tasks) becomes better and better until at a certain level of complexity it surpasses the whole-task. When task organization level was introduced as a variable, however, the trend was reversed; as a task became more highly organized, whole-task training became better for more complex tasks. Thus, it can be seen that careful task analyses must be performed, especially concerning the organization and complexity of a task, before a training strategy is dediced upon.

Much to the same point as the above study is Briggs and Johnson (1977). This is a lengthy study investigating the effects of interacting variables on learning. This study used a series of written deciphering tasks, ten to a block, and varied the spacing of the trial blocks, the frequency with which subjects were provided with knowledge of training standards, and the manner in which these standards were presented. None of these variables showed any significant main effects, but various combinations of the three were found to produce significantly better performance than other combinations. The authors suggest, therefore, that in implementing any training devices, the interaction of new and old training methods must be studied first.

Of course, the most important objective of training is to ensure that the material is acquired, retained, and transferred to the operational setting. One interesting study, Dansereau (1975), describes various principles of abstract learning and applies them toward developing better study habits. This might well serve as an introduction to any training program by outlining ways of enhancing learner strategies through techniques such as imagery linking, rehearsal, etc.

A study which directly investigated factors influencing the transfer of training was Briggs and Johnson (1976). This study measured the transfer of tasks trained under simple conditions to a more complex situation. A task involving speed and accuracy was trained, one group being trained for speed, the other for accuracy. In transfer, if the groups were asked to maximize performance in the other condition, no significant decline in performance occurred. If they were asked to maximize both aspects, however, both suffered a decline.

Another section of the experiment involved training using verbal coordination of team efforts but no visual coordination (i.e., each member had his own instrument readout), visual but no verbal (they worked off the same instruments but did not discuss what they were doing), or both. "Visual" and "both" were not found to differ from each other, but each was significantly better than "verbal" alone.

In addition, teams trained together showed no superiority over teams which were remixed for transfer trials. It was suggested that any special efforts made to train teams in the same arrangement in which they will be working will probably be wasted.

One area of particular interest in training is the proper use of feedback. The utilization of feedback in training was examined in a study by Schuster (1978). In this study, drivers were trained in one of four ways: no feedback, a test but no knowledge of results, a test yielding instant knowledge of results, and two such tests taken a week apart. The fourth group had significantly fewer accidents and violations during the first year of driving than the first group, although there was no difference between the groups during the second and third years. Possibly, the group trained with the benefit of feedback achieved a performance level in one year that it took the other group two years to achieve.

Another paper which is particularly valuable in applying various principles of behavior and learning to instructional effectiveness is Bailey and Hughes (1978). This paper identifies and explains these principles in terms of simulator training. Reinforcement should be used by identifying correct behaviors and providing some positive feedback for proper performance. Conversely, it might also be effective to arrange aversive feedback for incorrect performance. **Shaping** is described as systematically adding complexity to the training task, starting at a fairly low level. This way, the trainee is able to be reinforced immediately and can continue to be reinforced as he progresses. **Chaining** is a technique in which the training task is broken down into a series of smaller units. The units are then practiced to criterion, the last one alone is practiced first, then the last two alone, the last three, and so on. Supposedly, one problem in learning long sequences is that the early segments are too far removed from the reinforcement of performing the task correctly. The backward chaining technique is designed to overcome this. **Prompting and fading** is used by providing a student explicitly with information he will eventually have to derive from the environment. As training progresses, this explicit information is gradually removed and the student learns to acquire cues on his own. **Discrimination and simulus control** is described as learning to perform by responding to changes in the stimulus input, and being able to distinguish the meanings of the various inputs. Finally, **generalization** refers to applying the meanings one derives in one situation to other appropriate situations.

Bailey and Hughes also discuss the role of task analysis in training techniques. The three major areas here are component analysis (in which components of a task are first learned separately and then learned concurrently), chain or sequence analysis (which relates to the backward chaining technique described above), and dimension of difficulty analysis (involving identifying the difficult aspects of a task and presenting "watered-down" versions of these aspects early in training, gradually increasing them in complexity). The major thrust of the paper, then, is a description of ways to use the simulator as a training device rather than merely as a poor substitute for a real life situation.

Finally in the area of training techniques is an article which provides a very detailed overview of many aspects of the question of efficient training. Caro, Shelnutt, and Spears (1980) describe many different factors influencing transfer of training. The major thrust of the paper is that behavior should not be considered a response to a stimulus per se, but rather as an appropriate action taken in light of the meaning of the stimulus, that is, performance is guided by **cues**. Thus, trainees should be taught mediational processes, learning the meanings of stimuli, and not just the responses to the stimuli. Next, trainees should learn cue and response discriminations — noticing the difference in meaning of various similar stimuli, skills should be taught in hierarchies so that more complex skills can be built on simpler ones. Here, simulators can be particularly useful in practicing components of complex skills that cannot be isolated in real life. Finally, the trainees should be taught to generalize, that is, to apply skills in a situation different from the one in which they were learned.

According to this view, the physical stimuli in the simulator need not be identical to the real life situations as long as the psychological fidelity is high, that is, the same meanings can be extracted from stimulus situations. The important thing is that students be trained in mediational processes, the extraction of meaning from situations, and thus the use of classroom and text instruction is valuable. Also, the trainees should be encouraged to "talk themselves through" learning situations. In this way, instructors can see what the students are attending to and if the proper meanings are being extracted.

The authors also emphasize the importance of feedback in training, both to maintain the student's motivation and to inform him of the appropriateness of his interpretations and actions. Intrinsic feedback is the natural result of the performance itself, and the meanings usually have to be learned. One thing suggested in this paper is that salient aspects of intrinsic feedback can be highlighted in the simulator to enhance learning. In addition, there is supplemental feedback (which is not inherent in the situation) which could perhaps be provided by the instructor pointing out the results of an action. This would help the trainee acquire cue meanings and discriminatory ability. The timing of feedback is important as well, especially when the relationship between cue and response is not clear and immediately recognizable. In this case feedback must be virtually instantaneous and the simulator should be used to provide this rapid feedback where a real-life situation might not.

The concept of training in this paper is that of guidance, that is, directing the actions of the trainee to a desired goal. This speeds learning by presenting meanings of cues and their proper relations to responses, thus eliminating the waste of learning by trial and error. Written and oral instruction and demonstrations all should be incorporated into the simulator training program to this end. These ideas are developed in the paper and detailed summaries are provided.

INSTRUCTOR CHARACTERISTICS

The paper by Caro, Shelnutt and Spears discussed immediately above also provides a useful discussion of certain aspects of instructor characteristics. The major thrust of this discussion is that simply taking an expert pilot (or shiphandler) and placing him as an instructor is not always beneficial. Many times, an experienced pilot will feel he is being "stuck" in an undesirable situation, and this attitude must interfere with his ability to teach. Further, the expert is not necessarily familiar with the instructional techniques which can be used on a simulator and tends to see the tasks holistically, using the simulator as a substitute ship, which does not utilize its training potential. The authors suggest that instructors should be selected for their desire to be instructors, should be trained in instructional techniques, not only in shiphandling, and should not have to compete with regular ships officers in terms of advancement and recognition. The case for the instructional specialist is strongly made in this paper.

Another paper was located which also suggests the same thing. Caro (1976), in a long and speculative paper, identifies a few instructor characteristics. The author says an experienced pilot does not make a better instructor than someone who is specifically trained as a simulator instructor, although students may have more confidence in the experienced pilot. The author offers several suggestions which are speculative, but noteworthy: good instructors teach what is needed for the assignment, not everything they know; good instructors do things to simulate operational situations; good instructors let trainees go further before hitting the freeze button; and good instructors concentrate on trainees' needs rather than on just getting through the syllabus.

Certain aspects of instruction behavior that might influence the ability of students to learn have also been investigated. One paper, Land (1979), identified several behavioral variables which made a teacher presentation "clear" or "unclear." The author video-taped a "clear" lecture and an "unclear" one and measured the performance of students taught by each. Students taught by the clear tape performed better on a test immediately following the lecture. It might be valuable, therefore, for instructors to be trained in clarity of presentation, since this can be quantified, and does appear to affect student learning.

Another article investigating instructor behavior was found to be particularly applicable. Krahenbuhl and Reid (1980) assert that stress is a main cause of failure in training programs. Research is cited indicating that high levels of arousal bias a students' search process toward readily available responses, which is not appropriate in a learning situation. The experimenters categorized various instructor behaviors into commands, instructional cues, questions, acceptance, general praise, specific praise, general scold, specific scold, correction, positive modeling, and negative modeling. These categories were classified as negative or positive and certain ratios were established to characterize instructors as either positive or negative. Physical indices of student stress levels were measured and it was found that students of negative instructors experienced significantly more stress than did students of positive instructors; thus the former suffered in training. This study is significant in identifying specific behaviors which cause stress in students, thus *enabling instructors to be trained to avoid them.*

The above study, generally speaking, seems to indicate that the person-to-person interaction of instructor and pupil can affect learning. A report by Coehls (1979) is an informal and rather prosey discussion of the interpersonal relationship between instructor and pupil. This might be interesting for prospective instructors to read before entering the training situation.

Finally, a description of how the instructor should be involved in all aspects of training is provided in Charles (1977) (NTIS No. AD-A047919). This paper breaks down the role of the instructor into discrete segments and analyzes the procedures for achieving these segments. The major segments are: Preparation, Briefing, Initialization, Training, Evaluation, Debriefing, Data Management, and Syllabus Development. These segments are further broken down into 35 sub-functions which are explained in the report. In this view, the instructor interacts with the training curriculum so that the curriculum design is a dynamic and flexible procedure which can be tailored to the needs of the student and the capabilities of the instructor.

SUMMARY

Reading the current research literature on training makes it fairly evident that training is developing into a science and the simulator can occupy a key role in its development. It is being recognized that training can be carried out much more rapidly and less expensively if it is approached systematically, and ways are being developed to accomplish this. In order to know how best to teach it must be known exactly what to teach, what tasks are involved, and what basic skills are needed to perform these tasks. The importance of this kind of task analysis is becoming evident and procedural guidelines have been developed to standardize and facilitate the process. Once the tasks have been analyzed, various methods of presenting the material can be used, employing what is known about human learning and behavior, to help the student understand what information he needs to make his decisions, how to use the information, what his responses ought to be, and how best to carry out those responses. The role of the instructor is under investigation as well, and behaviors that can facilitate or interfere with the learning process are being identified as specifically as possible. The simulator can and should be used to present certain information and in certain arrangements which facilitate learning and which cannot be presented in the natural environment. It is the new job of the instructor to understand the science of training, in addition to the science of shiphandling.

One view of the process involved in shiphandling reduces this process to a scientifically manageable level and suggests a direction for future research. Shiphandling, and indeed most similar activities, can be seen as a series of decisions which must be made. In order to make these decisions correctly, the shiphandler must extract certain information from the environment on which to base them. This information is available either directly from the environment or indirectly via the ship's instrumentation and comes to the shiphandler through various perceptual states and events. Thus, it is vital that the shiphandler trainee learn where to locate the specific information he needs in a particular instance, and how to correctly interpret the perceptual events that contain the information. What is needed, then, is research to determine exactly what information is used by the expert shiphandler in the performance of his tasks. If this information and its location in the environment can be identified, the attention of the trainee can then be directed toward it, thus speeding the training process. In addition, the meanings of various states and changes in the environment can be taught directly, hopefully lessening the number of things the trainee must learn for himself through experience. The simulator can be used in this way to highlight and provide meaning to the information-bearing aspects of the environment. This extra information can be phased out gradually as training progresses, thus leaving the trainee better able to deal with the problems he will face in the real-life situation.

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